SEWAGE WORKS JOURNAL

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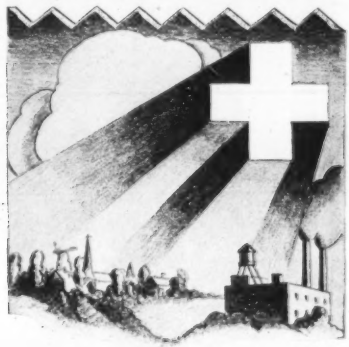

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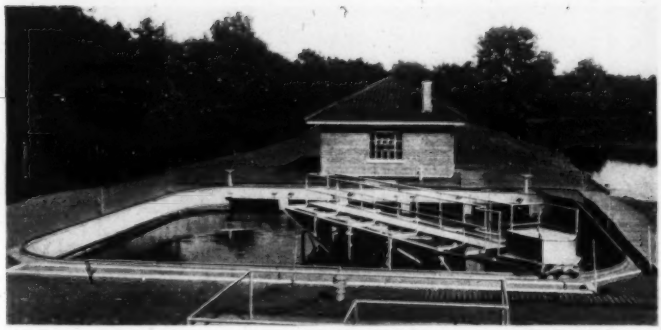

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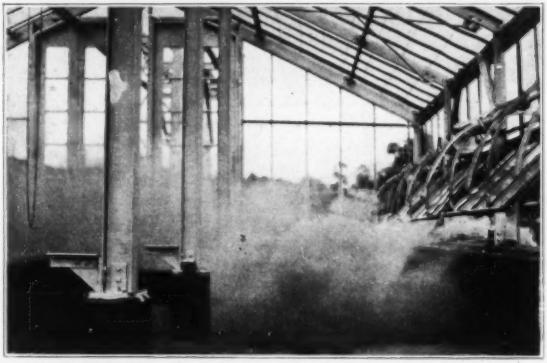

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Sewage Research

Observations on the Reliability of Different Methods for Determining the pH of Sewage Sludge

By Gordon M. Fair[1] and Edward W. Moore[2]

Publication in This Journal[3] of McCrumb's paper on "Determining the pH of Sewage Sludge by the Dilution Method" seems to warrant placing on record some of the results obtained by the authors in a study of the advantages and reliability of different methods for determining the pH of sewage sludge. Four methods were studied entailing the use of (1) the quinhydrone electrode, (2) the LaMotte Model 3B pH-testing Set, (3) the LaMotte Sludge-testing Set and (4) the Medalia Comparator.[4] Since the procedure commonly involved in determining the pH of colored or turbid liquids by these four methods is fully described in the technical literature,[5] it will not be repeated here.

The authors' measurements were planned with a view to selecting from the four methods listed one which would best satisfy their needs in laboratory studies of sludge digestion. To this end their investigations covered (1) the reliability of pH determinations by the dilution method as a whole and (2) the relative reliability of pH determinations by the four methods selected.

Reliability of pH Determination by the Dilution Method. —Reduction of the concentration of suspended solids which interfere in all methods of pH determination of sludge may be accomplished by sedimentation, centrifuging, filtration through glass wool, asbestos or paper, and dilution with water. The last of these seems to give the best results because it can be readily applied in such a way as to reduce the concentration of suspended solids without affecting the pH. Two things must, however, be avoided if

[1] *Associate Professor of Sanitary Engineering.*

[2] *Research Assistant in Sanitary Engineering, Harvard University, Cambridge, Mass.*

[3] Vol. 1, No. 5, Oct., 1929, pp. 533–544.

[4] This fourth method is here called the Medalia comparator method for simplification of statement. It involves use of Medalia's drop ratio procedure in connection with a comparator block.

[5] W. M. Clark, "Determination of Hydrogen Ions," 3rd Ed., 1928, William and Wilkins Co., Baltimore, Md. J. Howard Brown, *Journal of Laboratory and Clinical Medicine*, **9**, No. 4, Jan., 1924; also "The ABC of Hydrogen Ion Control," 5th Ed., 1929, LaMotte Chemical Products Co., Baltimore, Md. F. R. McCrumb, This Journal, **1**, No. 5, Oct., 1929. Leon S. Medalia, *Journal of Bacteriology*, **5**, No. 5, Sept., 1920, and **7**, No. 6, Nov., 1922.

determinations of pH from the diluted sample are to be reliable. These are (1) loss of CO_2 by aeration, and (2) dilution in excess of the buffering power of the sludge. Loss of CO_2 can be guarded against by introducing the sludge to be tested below the surface of the diluting water and making the pH determination as soon as possible after dilution. The lower the dilution the sooner should the sample be tested; for the greater the relative volume of diluting water the more CO_2 can it absorb.

How much the sludge can be safely diluted depends upon its buffering power, which may vary for different sludges. The effect of dilution on the pH of two sludges tested by the authors is shown in Table I and Figure 1

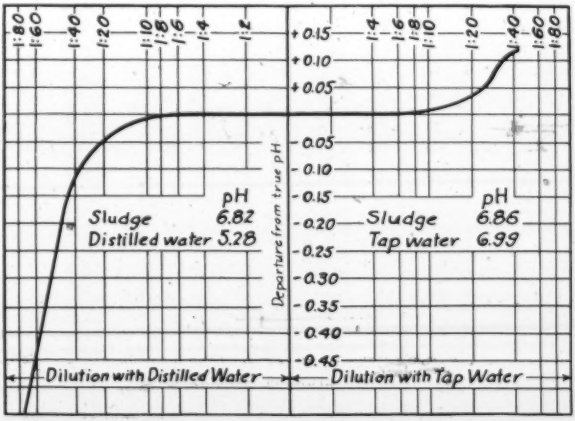


FIG. 1.—Effect of Dilution on pH of Imhoff Sludge. Dilution Is Expressed as the Ratio of the Sludge Volume to the Volume of the Diluted Sample.

for Imhoff sludge and in Table II for fresh sludge. The results presented were obtained by diluting a sample of sludge with successively larger amounts of distilled water or tap water, pH determinations being made by means of a quinhydrone electrode.

The results clearly show the buffering ranges of the sludges tested. Although the two sludges and the diluting waters varied widely in character the degree of dilution that yielded results within 0.05 pH of the true value was about the same. Dilutions less than 1:20 apparently gave satisfactory results in all cases.

Relative Reliability of pH Determination by Different Methods.—The relative reliability of pH determinations by the three colorimetric methods

TABLE I

EFFECT OF DILUTION ON pH OF IMHOFF SLUDGE

The pH values of the distilled and tap water were 5.28 and 6.99, respectively. The degree of dilution is expressed as the number of unit volumes of water added to one unit volume of sludge.

Dilution	pH of Sample Diluted with Distilled Water	Tap Water	Dilution	pH of Sample Diluted with Distilled Water	Tap Water
0	6.82	6.86	40	6.60	6.98
3	6.81	6.86	45	6.54	6.99
4	6.81	6.86	50	6.45	6.99
5	6.82	6.88	60	6.36	..
6	6.82	6.88	70	6.28	..
8	6.82	6.88	80	6.20	..
10	6.82	6.88	90	6.15	..
15	6.79	6.88	100	6.08	..
20	6.76	6.90	120	5.95	..
25	6.74	6.92	140	5.88	..
30	6.72	6.95	180	5.81	..
35	6.67	6.97	220	5.76	..

TABLE II

EFFECT OF DILUTION ON pH OF FRESH SLUDGE

The pH of the tap water was 6.97. The degree of dilution is expressed as in Table I.

Dilution	0	2	4	6	8	10	15	20	41	83
pH of sample	4.90	4.90	4.90	4.90	4.90	4.90	4.93	4.98	5.05	5.34
Dilution	111	148	198	264	358	477	955	3830	30,700	489,000
pH of sample	5.55	5.78	5.97	6.13	6.24	6.34	6.49	6.68	6.75	6.78

selected was tested against the quinhydrone electrode for Imhoff sludge (1) diluted with water and (2) treated with an acid (H_2SO_4) or a base (NaOH). Taking the potentiometric results as a basis for comparison, the divergence of findings by the three colorimetric methods is shown in Tables III and IV.

A study of these tables shows among other things that the LaMotte 3B Set and the LaMotte Sludge-testing Set seem to yield results of equal reliability. The poorer showing of the Medalia Comparator is laid by the authors to the large diameter (20 mm.) of tubes employed in their set. Smaller tubes would probably give as reliable results as can be obtained by the other colorimetric methods. More important is the fact that where the pH of the sludge has been changed appreciably by adding an acid or base, the colorimetric methods become unreliable. Dilutions beyond 1:25 also seem to decrease the accuracy of colorimetric pH-determinations.

CONCLUSIONS

As far as the reliability of the dilution method is concerned, the results obtained by the authors are much the same as those reported by McCrumb[1]

[1] *Loc. cit.*

TABLE III

COMPARISON OF pH READINGS FOR DILUTED IMHOFF SLUDGE

Dilution is expressed as in Table I

Dilution	No. of Samples	pH by Quinhydrone Electrode	Difference in pH Reading as Determined by LaMotte 3B Set	Sludge Testing Set	Medalia Comparator
5	3	6.82, 6.83, 6.95	−0.02, +0.02, +0.05	+0.08, +0.07, −0.05	−0.02, −0.03, −0.05
10	4	6.82, 6.85, 6.83, 6.97	−0.02, +0.05, −0.03, −0.02	−0.02, +0.05, −0.03, −0.07	−0.02, +0.15, +0.07, −0.17
15	3	6.85, 6.82, 6.94	−0.05, −0.02, −0.04	−0.05, −0.02, −0.04	−0.05, −0.02, −0.14
20	3	6.83, 6.81, 6.88	−0.03, −0.06, −0.08	−0.03, −0.01, −0.08	−0.03, −0.01, −0.18
25	4	6.84, 6.75, 6.75, 6.82	−0.04, 0.00, −0.05, −0.02	−0.04, +0.05, +0.05, −0.02	−0.04, +0.05, +0.15, −0.02
30	3	6.88, 6.67, 6.76	−0.08, +0.03, −0.06	+0.02, +0.13, +0.04	+0.02, +0.03, +0.04
35	3	6.92, 6.58, 6.78	−0.02, +0.02, −0.08	+0.03, +0.12, +0.02	−0.02, +0.12, −0.08
40	3	6.97, 6.98, 6.76	−0.07, −0.08, −0.06	+0.03, +0.02, +0.04	+0.03, +0.02, +0.04
45	2	7.00, 7.00	−0.10, −0.10	+0.10, +0.10	+0.10, 0.00
50	2	6.99, 6.98	−0.04, −0.08	+0.11, +0.12	+0.21, +0.12
Maximum difference, total			0.10	0.13	0.21
Below dilution 25			0.08	0.08	0.18
Mean difference, total			0.047	0.057	0.064
Below dilution 25			0.035	0.045	0.065
Above dilution 25			0.063	0.073	0.063

Table IV

Comparison of pH Readings for Imhoff Sludge

Treated with an acid or a base

Cc. of Normal Acid or Base Added to 100 Cc. of Sludge	pH by Quinhydrone Electrode Dilution 0	Difference in pH Reading as Determined by LaMotte 3B Set Dilution 0	LaMotte 3B Set Dilution 10	Sludge-Testing Set Dilution 0	Sludge-Testing Set Dilution 10	Medalia Comparator Dilution 10
NaOH						
0	7.24	....	....	....	....	....
0.25	7.31	+0.09	+0.01	....	−0.01	−0.11
0.5	7.46	+0.04	−0.01	....	−0.16	−0.36
1	7.63	+0.07	+0.07	....	+0.07	−0.13
2	7.79	....	−0.09	....	−0.09	−0.49
3.5	9.02	....	....	+0.08	−0.07	....
H_2SO_4						
0	7.06	....	....	....	....	....
0.25	7.05	−0.05	0.00	−0.05	−0.05	+0.03
0.5	7.05	−0.05	−0.05	−0.10	−0.05	−0.05
1	6.79	+0.06	−0.09	−0.09	−0.09	−0.09
2	6.37	+0.03	+0.03	+0.23	+0.23	+0.13
5	4.44	+0.86	+0.56	....	....	....

The colorimetric determination of pH by the dilution method is apparently satisfactory if the dilution is not too great. Dilutions less than 1:20 gave reliable results for the sludges tested.

There seems to be little difference in the reliability of the LaMotte 3B Set and Sludge-testing Set. The Medalia Comparator can probably be adapted for the testing of sewage sludges by employing small-bore test tubes. For laboratory work involving pH readings of many samples, the authors have selected the LaMotte 3B or 5B Set because it requires a smaller sample of sludge and is less time-consuming than the other methods studied.

Recent Experimental Sewage Treatment Work in Europe

BY G. P. EDWARDS[1]

A great deal of experimental work on sewage treatment is in progress in Europe, particularly in Germany. New methods are being perfected or old ones modified. New plants are being built which will test some of these new ideas.

In Germany progress is being made in the improvement of the operation and extension of the use of the submerged contact aerators. Activated sludge treatment, using wooden paddles for mechanical agitation in combination with compressed air, is being tried by many cities because of the expected low overall power requirement. The rotation of sludge, in order to speed digestion and to increase the yield of gas, is receiving particular attention. The heating of digesting sludge and the collection of gases are becoming more important, especially for the disposal of the increased amounts of sludge from submerged contact aerators and the activated sludge process. In Great Britain a great deal of interesting experimental work is being done on reaeration of activated sludge. The experimental work on different types of activated sludge carried on by the City of Paris will determine the type of activated sludge plant to be constructed there in the near future.

Germany

Ruhrverband-Rellinghausen.—Some very interesting experiments on stage operation of sewage treatment processes were started early in August, 1929. One series comprises three paddle-wheel aeration tanks, with settling tanks between each aeration unit (Figure 1). A total aeration period of two and one-half hours is being used. The volume of air required is about half the volume of sewage treated (0.07 cu. ft. per gallon). Another series of tanks consists of three stages of submerged contact aerators, with settling tanks between each stage (Figure 2). A total detention period of 1.5 hours is being tried. The racks, instead of hanging vertically, are fixed on pivots so that they may be suspended at a small angle from the vertical. They are turned from time to time so that either side may be exposed to the air.

Different materials are being tried as contact surfaces in the submerged contact aerators. Pieces of cork two or three inches in diameter are being used. When in operation the cork is held down by a wire netting. When the wire netting is removed the cork floats and cleans itself. To replace the cork the netting must merely be fastened down. At Iserlohn burlap-covered frames were being installed.

[1] *Principal Asst. Chemist, The Sanitary District of Chicago.*

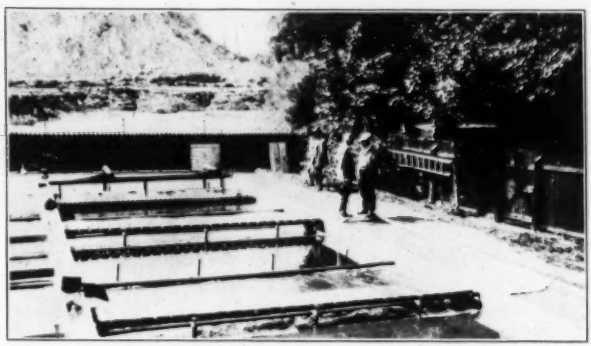


FIG. 1.—Stage Operation of Paddle-Wheel Activated Sludge—Rellinghausen.

A modified Dorr clarifier under construction will contain a deep sump in the center large enough to permit sludge accumulations of 10 to 11 hours. It is proposed to add ripe sludge intermittently to the sump in order to prevent acid digestion during the storage period.

Hattingen.—An interesting type of grit chamber construction is installed at the Hattingen treatment works (Figure 3). It is designed to maintain a rate of approximately one foot per second at all flows. As shown in the illustration, the grit chamber is divided into two sections.

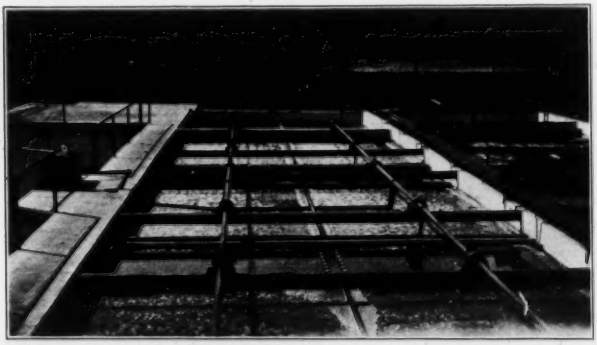


FIG. 2.—Stage Operation of Submerged Contact Aerators—Rellinghausen.

FIG. 3.—Grit Chamber—Hattingen.

During dry weather only one section is used, but during storms both parts are thrown into service.

Two stages of submerged contact aerators are being tested. The total detention period is 2.5 hours, which is divided into one 0.75-hour period for each of the two aerators and one 0.50-hour period for each of the settling tanks.

Mansfeld.—The Mansfeld plant offers an example of the treatment of industrial wastes with the aid of submerged contact aerators and activated sludge. The sewage reaches the plant from two sources in two separate sewers.

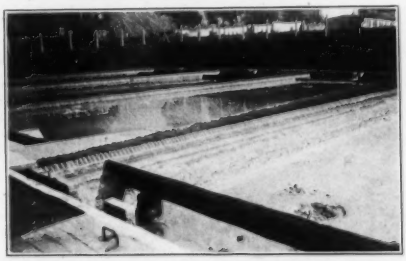


FIG. 4.—Underdrained Settling Basins—Mansfeld.

About 35 per cent of the total sewage, in one sewer, contains two grams of phenol per liter, introduced in by-products coke wastes. This waste is first settled in an underdrained settling basin for four hours (Figure 4). The lime and tar settle out. When the beds are full of sludge, they are withdrawn from service, the sludge is dried and removed and the basin is again used for settling.

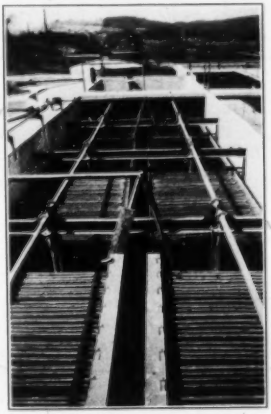


FIG. 5.—Submerged Contact Aerators—Iserlohn.

The remaining 65 per cent, in a second sewer, is domestic sewage from 3000 people. This passes first through an Imhoff tank, which has been in service twenty years. The settled sewage is mixed with the settled phenol waste. The mixture, containing about 700 p. p. m. phenol, is first treated in submerged contact aerators and then in activated sludge tanks. The contact aerators effect a 30 per cent reduction in phenol and the pH is lowered from 8.5 or 9.0 to 8.0. The proportion of air to sewage is about 6.7 to 1 (0.9 cu. ft. per gal.). The proportion of air to sewage in the paddle-wheel activated sludge tank, with a five-hour period, is about 13 to 1 (1.7 cu. ft. per gal.). The effluent contains less than 25 p. p. m. phenol.

Activated sludge without the tauchkörper was used unsuccessfully for a

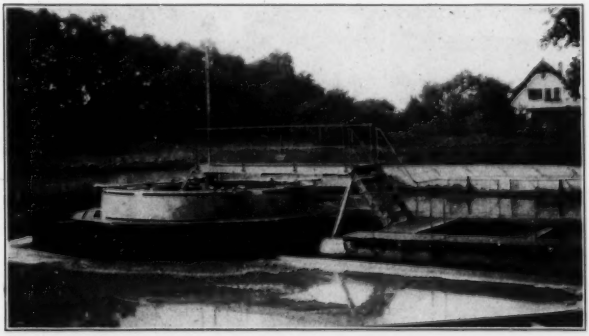


FIG. 6.—Preliminary Settling Tank—Essen-Nord.

year. Larger amounts of phenol than usual stopped all purifying action in the aeration tanks. The tauchkörper seems to be less sensitive to trade wastes, in general, and especially to sudden variations in amounts of waste.

Iserlohn has the first sewage treatment plant operated solely by power generated by the gases of digestion. No outside source of power is used in the plant. The treatment works consist of Imhoff tanks, submerged contact aerators (Figure 5) and paddle-wheel activated sludge. Three cubic meters of gas per capita per year (0.29 cu. ft. per capita per day) have been obtained from the Imhoff tanks from the preliminary settled solids alone. An equal amount of gas is expected from the digestion of excess activated sludge and the sludge from the tauchkörper.

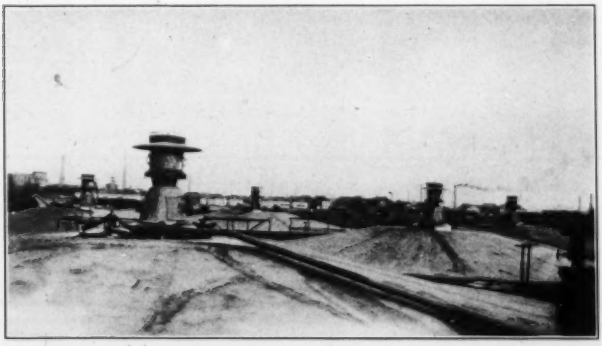


FIG. 7.—Separate Sludge Digestion Tanks Fitted with Sludge Rotation Apparatus—Gelsenkirchen.

Emschergenossenschaft-Essen-Nord.—A new type of settling tank at Essen-Nord seems to show promise of effectively dewatering sludge with a short storage period. An old storm water settling tank has been converted into a preliminary settling tank by installing a deep well in the center (Figure 6). The sewage enters the tank at the center and flows to the sides. The solids settling in the tank are removed by a mechanical revolving scraper which forces the sludge and scum into slots in the center well. The tank treats about 470,000 gallons per hour. With 20 to 25 minute detention periods, about 75 per cent of the settleable solids are removed. The cost of construction is estimated as being less than the cost of fine screens for a like amount of sewage.

Gelsenkirchen.—An interesting series of experiments on the heating and rotation of sludge has been started at Gelsenkirchen. The sewage

received at the treatment works is settled in Imhoff tanks, but since the digestion space is too small for satisfactory operation, six separate sludge digestion tanks, each with a capacity of about 180,000 cu. ft., have been constructed (Figure 7). The fixed cover is lined with sheet lead $1^1/_2$ mm. thick in order to prevent gas leaks, and it is insulated by a covering of earth. The tanks are fitted with apparatus for rotating the sludge. To determine the effect of rotation and of heating, the six tanks are being operated as follows:

1—Sludge rotated, not heated
2—Sludge quiescent, not heated
3 and 4—Sludge quiescent, heated
5 and 6—Sludge rotated, heated

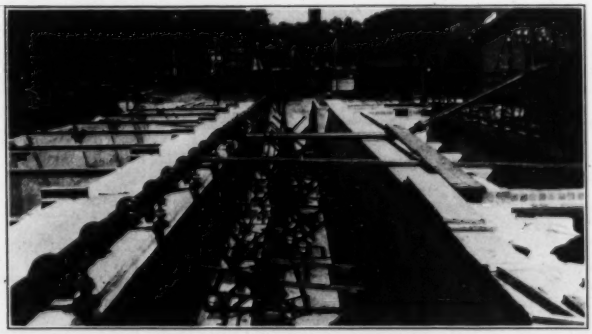


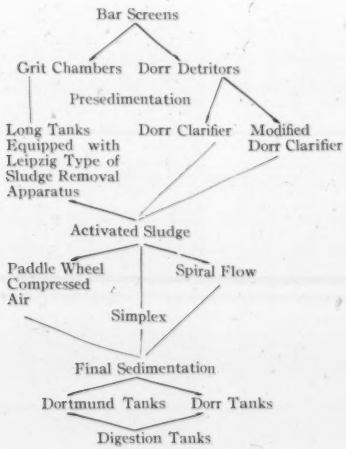
FIG. 8.—Paddle-Wheel Aeration Tanks—Leipzig.

After digestion for several weeks in the Imhoff tanks, the sludge is pumped to the secondary digestion tanks. Before entering Tanks 3, 4, 5 and 6, the sludge is heated to about 25° C. in heat exchangers. As these tanks are operated under identical conditions in other respects, accurate data should be obtained concerning the advantages and disadvantages of rotating and heating sludge.

Leipzig.—An experimental plant has been constructed at Rosenthal which includes Imhoff tanks, submerged contact aerators and paddle-wheel activated sludge tanks. A sewage flow of about 10,000 to 15,000 gallons per hour is treated. The sewage as received is very strong and septic. The paddle-wheel activated sludge tank requires a proportion of air to sewage of 6 to 1 (0.8 cu. ft. per gallon) (Figure 8). Compressed-air aeration at Leipzig requires a proportion of 10 to 1 (1.3 cu. ft. per gallon).

The excess activated sludge and sludge from the tauchkörpers are digested in the Imhoff tanks. Two new tanks are under construction, one for the reaeration of activated sludge and the other for installation of the Haworth process of mechanical aeration. Experimental work at the new treatment works at Wahren has indicated that the use of tauchkörpers before the paddle-wheel activated sludge tanks will reduce the aeration period in the activated sludge from 10 or 12 hours to 4 hours.

Berlin.—The Stahnsdorf treatment works now under construction will really be operated on a large-scale experimental basis. The plant, which will have a capacity of about 48 million gallons per 24 hours, will be so arranged that many types of apparatus and treatment can be used. The following diagram shows the proposed arrangement.



All the sewage will pass through the sedimentation tanks but only about 24 million gallons, or approximately the present dry-weather flow, will be treated by activated sludge. From small-scale operation it was determined that the aeration period should be about 6 hours with 20 per cent returned sludge. About 6 volumes of air to one volume of sewage (0.8 cu. ft. per gal.) will be necessary. Twenty aeration tanks 70 ft. wide, 230 ft. long and 13 ft. deep are being built.

The excess activated sludge and preliminary sludge will be digested three days to dewater it before it will be pumped to the final digestion tank. It will pass through heat exchangers similar to those being used at Gel-

senkirchen, in which it will be heated to 21° to 23° C. before entering the final digestion tanks. There it will be digested about three months. Sludge rotation according to the Prüss scheme will be used in some of the tanks. Gas will be collected and used for power.

Small-scale sludge digestion experiments with the Prüss sludge rotation scheme have been carried on for nine months. According to the data, the sludge has digested more rapidly and 20 to 30 per cent more gas has been obtained than without rotation. The gas contained about 18 to 20 per cent more carbon dioxide than was found in the gas from the non-rotated sludge.

France

Paris.—The experimental station at Colombes has investigated three systems of activated sludge: simplex, diffused air and the Lamy process.

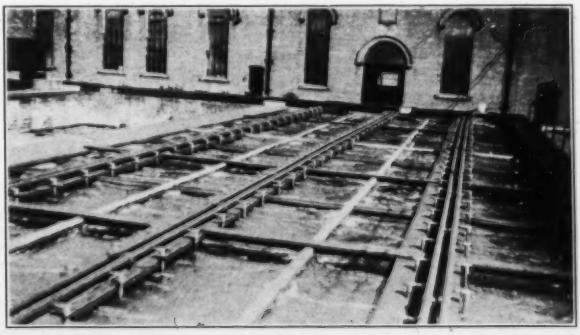


FIG. 9.—Experimental Activated Sludge Plant—Glasgow.

The latter scheme consists of a tank with a vertical down-well, which reaches nearly to the bottom of the tank. The sewage, returned sludge and air are added at the top of the trapped down-well, flow out of the bottom and rise to the surface. No data on operation were available.

Great Britain

Sheffield.—Haworth is trying one of his aeration units on a fill-and-draw basis to eliminate the necessity of using nine small hopper-bottom settling tanks for one aeration unit. The main objection to fill-and-draw schemes is the time necessary for filling and drawing. In general practice, Haworth empties a tank in forty-five minutes without disturbing the settled

sludge. The tank is three feet deep and has a flat bottom, except for a seven-foot sump at one end. The tank is filled with sewage and the required amount of sludge and the contents are circulated for the customary period. The paddles are shut off, the sludge allowed to settle one-half hour, and the clear supernatant liquor and the excess activated sludge are drawn off from the deep end of the tank. An automatic device gradually lowers the level of the drain. The tank is then refilled and the paddles started. The operation of drawing is almost entirely automatic and requires a minimum of labor. Since the tanks had been in operation only a few weeks, no data were available.

Glasgow.—At Shieldhall an experimental spiral-flow activated sludge tank, which has been made from an old settling tank, treats about 300,000 gallons per day (Figure 9). The sewage requires 1 cu. ft. of air per gallon with an aeration period of $6^1/_4$ hours. Reaeration of sludge had been used for some time successfully, but during the summer it was discontinued. In a short time poor results were noted and reaeration was resumed.

Birmingham.—Important work on short-period aeration of settled sewage before treatment on sprinkling filters is showing very good results. The capacity of the filters is being increased about twice. A new aeration unit to treat 12,000,000 U. S. gallons per day, which is about one-third of the total settled sewage received at Minworth, is about to go into operation. The new tanks will be of the diffused-air type with a 60° sloping bottom on both sides of a row of porous plates. Preaeration of the settled sewage before addition of the activated sludge will be tried. The sewage with the activated sludge will be aerated one hour. The sludge will be reaerated four or five hours.

Interesting work is also being carried on at Manchester, but time did not permit a visit to this city.

Separation of Fresh Sewage Solids by Aeration into Different Components and Their Digestion*

BY H. HEUKELEKIAN**

Studies on the digestion of sewage solids have demonstrated repeatedly that the digestion proceeds by different stages determined by the decomposition of various types of substances by different groups of bacteria. Bacteriological studies have demonstrated the presence of a succession of groups of organisms.[5] Chemical studies have enabled us to make certain deductions as to the nature of the stages of decomposition.[6] The purpose of the addition of certain organic substances, which are known to occur in fresh sewage solids, to digesting mixtures has been to study the differences in the course of digestion of different compounds.[1,3] The main drawback to this method of attack has been that the physical and chemical properties of the added pure substances did not always correspond to those occurring in fresh solids. A further attempt was made to obtain a natural variation in the composition of fresh solids and to correlate the composition with the digestion characteristics. It was observed that the composition of solids settling in different parts of a settling tank varied, at least in respect to fat, nitrogen and cellulose. The correlation of these variations with the digestion process have been published elsewhere.[2] It was felt, however, that if such variations in the composition of solids could be brought about experimentally, without materially affecting the physical condition of the components, a more definite correlation could be established. Since the fats are the most important constituents of the solids attention was directed toward solids containing a large percentage of fat.

Method

A quantity of fresh sewage solids was dried and part of the dried solids were extracted with ether. The extract, after evaporation of the ether, and the residue were returned to the ripe sludge. Quantities of the various components were added to ripe sludge to correspond to the untreated fresh solids in a 2:1 mixture (2 parts of volatile matter in fresh solids to 1 of ripe sludge). Care was taken to drive off all the ether used in the extraction. The experiment was set according to the following scheme:

(1) Fresh solids not dried, not extracted
(2) Fresh solids dried, extracted; fat and residue added to sludge
(3) Fresh solids dried, extracted; only residue from extraction added to ripe sludge

* *Journal Series Paper of the New Jersey Agricultural Experiment Station, Dept. of Sewage Disposal, New Brunswick, New Jersey.*

** *Bacteriologist, Dept. of Sewage Disposal.*

(4) Fresh solids dried, extracted, residue 2 × the quota of fat
(5) Fresh solids dried but not extracted
(6) Only grease added

All the mixtures with the exception of mixture (1) digested at an abnormally slow rate, therefore the results are not represented. During 60 days of digestion the quantity of gas produced was only a fraction of what was produced from the untreated fresh sludge and fresh solids mixture in 35 days. It was concluded that the change in the physical character of the substances due to drying and extraction were such as to make the materials resistant to decomposition. Therefore, this direct method of attack was given up.

In the course of certain aeration experiments with fresh solids it was found that air brought about a separation of solids, forcing the scum to float on the surface. It was thought that if the composition of this material could be shown to be markedly different from the residue, an interesting correlation between the composition of solids and their decomposition might be obtained. Accordingly, seven liters of fresh solids were aerated by means of diffused air for periods of 15 minutes and the scum collected on top was skimmed off. Skimmings from 3 different aeration periods of the same fresh solids were mixed. The skimmings, the residue after the skimmings had been separated, and the untreated solids were analyzed for fat and nitrogen.

Results

Table I gives the results of the analyses. The skimmings had a higher solids concentration and a lower ash content than the original solids. The

TABLE I

	Fresh Solids	Skimmings	Residue
Solids, per cent	5.45	12.3	4.49
Ash, per cent	25.0	15.1	24.0
Volatile matter, per cent	4.09	10.4	3.41
Quantity (wet), grams	8000	890	7110
Quantity (dry), grams	436	109.0	319
Fat in dry solids, per cent	28.8	36.5	22.6
Fat in dry solids, grams	125	39.8	72.0
Nitrogen in dry solids, per cent	3.04	2.18	....
Nitrogen in dry solids, grams	13.2	2.38	....

per cent of fat in the dried solids increased from 28.8 in the fresh solids to 36.5, an increase of about 27 per cent. The nitrogen content of the skimmings, on the other hand, decreased from 3.04 to 2.18 per cent, or a decrease of 28.3 per cent. It is also interesting to note that out of 125 grams of fats in the original fresh solids 40 grams could be separated with an aeration period of an hour.

The results of a second trial are given in Table II. The fat content of the original fresh solids was higher than in the previous test. The percentage of fat in solids increased from 35.3 per cent in fresh solids to 46.1

TABLE II

	Fresh Solids	Skimmings	Residue
Solids, per cent	6.35	11.7	4.9
Ash, per cent	23.0	18.9	24.4
Volatile matter, per cent	4.9	9.5	3.70
Solid (wet), grams	6000	700	6300
Solids (dry), grams	381	82.0	308
Fat in dry solids, per cent	35.3	46.1	32.1
Fat in dry solids, grams	134	38	99.0
Nitrogen in dry solids, per cent	4.1	3.1	4.4
Nitrogen in dry solids, grams	15.5	2.5	13.5

in skimmings, equal to an increase of 23 per cent. The nitrogen content of the skimmings decreased 24.0 per cent. The residue consequently contained a relatively lower percentage of fat and a higher percentage of nitrogen than the skimmings.

If composition of solids has influence on the course of decomposition, the differences in fat and nitrogen content of the skimmings, and the residue after separation of the skimmings by mechanical means, should modify the rate and course of digestion. Accordingly, portions of fresh solids, skimmings and residue containing equal weights of dry volatile matter were seeded with ripe sludge to yield a ratio of 2 fresh: 1 ripe on the basis of volatile matter. Thus, although the total weight of volatile matter added in all cases was the same, the composition of the solids varied, at least in respect to fat and nitrogen content. The ripe sludge-skimmings mixture contained the highest amount of fat and lowest amount of nitrogen, while the fresh solids had an intermediate position in these respects.

All mixtures were incubated at 80° F. and daily gas measurements were made. The daily gas production from each mixture is represented in Figure 1. It can be seen that gasification in the fresh solids-ripe sludge mixture (control) was normal, with an initial minor peak followed by a drop and an increase to the final peak within 18 days. The maximum rate of decrease of gasification occurred in 21 days and the low value of 10 cc. of gas per gram of raw volatile matter was attained in 24 days. The mixture of ripe sludge-residue followed the same trend except that the maximum rate of gasification was attained 4 days earlier and the digestion was completed 3 days earlier than in the control mixture. The mixture of skimmings and ripe sludge, after an initial peak in gasification similar to the others, rose only very gradually to its maximum peak which occurred after about 30 days. The peak was not so well defined nor as

high as in the other two, but was instead spread over an extended period. In 40 days gas production fell to the minimum of 10 cc. of gas per gram of raw volatile matter. Thus the digestion of skimmings-ripe sludge mixture was completed 15 or 16 days later than in the control mixture.

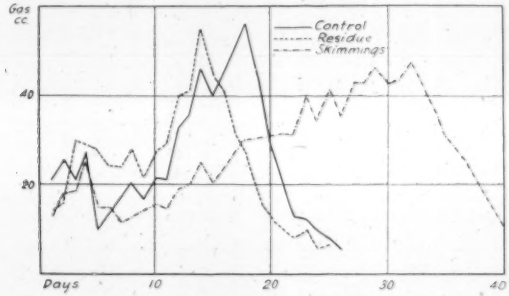


FIG. 1.—Daily gas production from seeded mixtures of (*a*) fresh solids, (*b*) skimmings after aeration of fresh solids and (*c*) the residue after removal of skimmings (per gram of raw volatile matter added).

The yields of gas per gram of total volatile matter in the mixture, as well as per gram of volatile matter added in the fresh solids, are given in Table III. The yield of gas was highest in the skimmings mixture and

TABLE III

	Fresh Solids	Skimmings	Residue
Total gas[a]	415	680	380
Total gas[b]	625	1030	580
Volatile matter red, per cent	40.4	47.0	44.5
Gas per gram vol. matter destroyed	1030	1450	855
CO_2, per cent	19.7	17.4	14.2
CH_4, per cent	66.5	68.6	77.1
CO_2, total cc.	220	250	121
CH_4, total cc.	685	995	660

[a] Per gram of volatile matter in mixture.
[b] Per gram of raw volatile matter added.

lowest in the residue. Fresh solids occupied an intermediate position. The reduction of volatile matter was similarly highest in the skimmings but lowest in fresh solids. Gas per gram of volatile matter destroyed was highest in the skimmings mixture and lowest in the residue. Thus the yield of gas seems to be directly proportional to the fat content of the digesting mixture (Figure 2).

All the gas evolved from each mixture was collected and stored over gas-saturated water and at the end analyzed for CO_2, O_2 and combustible gases. The percentage and volume of CO_2 and combustible gases from each mixture is given in Table III. The average composition of the gas is not materially affected by the differences in the composition of the digesting material. The carbon dioxide is lowest in the gas from the residue and highest in the gas from the fresh solids mixture. Combustible gases are highest in the gas from the residue and lowest in the gas from the fresh solids mixture.

Discussion

In a previous publication[3] an attempt was made to correlate the digestion of solids with their composition, based on certain differences in the composition of solids settling in various sections of a settling tank. However, these differences in the composition of solids collected from different parts of the settling tank were not constant, therefore it was difficult to draw definite conclusions. It was noted that the material settling in the inlet end was higher in cellulosic substances and usually lower in fatty substances than the material settling in the middle or in the outlet end of the tank. The digestion time was not materially affected by these differences in the composition of solids. Usually the digestion of material from inlet and outlet proceeded faster than the digestion of material from the middle of a mixture of all sludges. This was ascribed to the segregation or uniformity of the types of materials settling in various parts of the tank. A high fat content was not always correlated with high yield of gas. Since the solids for the various runs were collected at different times it is obvious that other factors not considered might have played a rôle in obscuring the results.

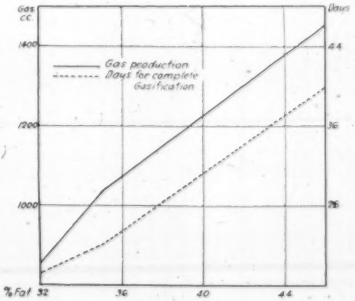


FIG. 2.—Correlation between (*a*) gas production and (*b*) days for complete gasification and the percentage of fat in the digesting material.

In the studies presented here the differences in the composition of solids were brought about artificially by aeration. In order to determine the direct effect of air itself on the course of digestion the following experiment was set up: Gas production from fresh solids (after seeding

with ripe sludge) was compared with gas production from similarly seeded but aerated solids (Figure 3). Gas was expelled from the solids during aeration so that for a few days after seeding gas production from the aerated mixture was low; but it soon overtook the non-aerated mixture. Gas evolution from this point on proceeded at a somewhat faster rate than in the control mixture, up to the 16th day, when it began to decrease at a faster rate than the control. The curves are in general similar except that the course of gasification in the mixture with the aerated fresh solids is accelerated by 2–3 days, as compared with the control. The gas yield per gram of raw volatile matter added is 650 cc. for the non-aerated mixture and 595 cc. for the aerated mixture. The lower yield of gas of the latter may partly be explained by the loss of entrained gas during aeration. It is doubtful whether aeration of half-an-hour brought about any fundamental change in the constitution of the organic matter that would result in a reduction of the yield of gas.

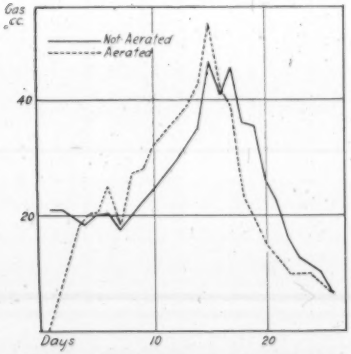


FIG. 3.—Effect of aeration of fresh solids on the digestion of seeded mixture (gas in cc. per gram of raw volatile matter added).

Differences in the digestion of skimmings and fresh solids are of a decidedly greater order than can be explained on the basis of the effect of aeration. On the other hand, the characteristics of the digestion of the residue in comparison with the untreated solids, namely, a somewhat shorter time of digestion and lower yield of gas, may partly be due to the effect of air, since aeration without any separation of solids brings about changes of a similar order. The effect of air would be more pronounced in the residue through which all the air is blown, rather than the small amount of skimmings.

It must be concluded that the slow rate of gasification and the higher yield of gas in the digestion of skimmings are not due to air *per se*, but rather to a change in the composition of solids brought about by aeration. The skimmings had a higher fat and lower nitrogen content. Not all the total nitrogen is organic, nor all the organic nitrogen is in the form of proteins, but for an approximation, considering the total nitrogen to be in protein form, protein would constitute 25.0 per cent of the fresh solids (4.1×6.25) while the fat content is as high as 30–35 per cent. It has been shown that the reduction in nitrogen during digestion is not large

while fats decompose to a great extent.[4] It would be reasonable, therefore, to attribute the differences in the digestion of skimmings to the high fat content. This would lead to the conclusion that the higher the fat content the longer the digestion time and the greater the gas yield will be (Figure 2). Fats would appear to digest at a slower rate than some other constituent of fresh solids. Since they constitute such a high percentage of the solids and a great part is ultimately decomposed, the rate of fat decomposition in general determines the rate of digestion of the solids.

In further consideration of the foregoing statements, if the main peak of gasification is due to the decomposition of fats and their products of hydrolysis, it is improbable that the initial minor peak, to which attention has been called, is also due to the same cause unless we assume that a different type of fat is decomposed at the initial stage. In view of the studies on the decomposition of cellulose,[1] which has been shown to take place very rapidly, it would seem that this initial peak is caused by the decomposition of cellulose and other readily decomposable substances.

The physical character of the skimmings is very much like the foam that forms on a foaming Imhoff tank. In a foaming tank the frothy substance is brought to the surface by gas particles while in skimmings it was produced artificially by blowing air. In case the foam is collected and digested separately as is sometimes done, it should be expected that a longer digestion time would be required than that generally allowed for digestion of fresh solids. It is furthermore known that scum which contains relatively high percentages of fatty substances is more difficult to digest than fresh solids.

It has been a practice at a number of plants to aerate the incoming sewage for short periods in order to separate the oils and greases and to facilitate the removal of scum. In view of the results reported in this paper it would seem that such practice is good not only for the removal of unsightly masses on top of the settling tanks, but also that it may help the rate of digestion of the settled solids. It might be expected, however, that such a procedure will lower slightly the total gas production. If, however, such skimmings are added in considerable quantities to the digestion tank after more or less prolonged intervals it is quite possible that this procedure would cause fluctuations in gas production and lead to operating difficulties, especially if the fresh solids are being added at a maximum rate to the ripe sludge or if the temperature of digestion is low during the winter months.

Summary and Conclusions

Making use of the separation of solids (scum) brought about by aeration of fresh sewage solids, the following observations were made on the composition and decomposition of the various components:

1. The material skimmed from fresh solids after the passage of air is higher in fat and lower in total nitrogen than the original fresh solids or the residue.

2. The residue after the fatty material is skimmed off digests somewhat more rapidly than the fresh solids.

3. The skimmings digest considerably more slowly than untreated fresh solids (14 to 15 days).

4. Gas yield from skimmings is decidedly higher than from fresh solids (about 40 per cent).

5. The average composition of the gas is not materially affected.

6. The differences in the rate of digestion of the skimmings cannot be explained on the basis of the direct effect of air.

7. When fresh solids are aerated for short periods ($^1/_2$ to 1 hour) without separation of the scum the subsequent rate of digestion on seeding is only slightly more rapid than the rate of digestion of the unaerated solids.

8. It would appear that the high fat content of the skimmings is responsible for the slower rate of digestion as well as the larger ultimate yield of gas.

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Results of Experimental Work on Outlet Structures, Los Angeles County Sanitation Districts[1]

BY A. M. RAWN[2]

Certain fairly well defined laws appear to control the dilution of sewage or fresh water when discharged into a body of water which has the salinity of ordinary ocean water. By trial and experiment certain relationships which exist between the depth, direction and quantity of discharge of the sewage jet, and the rapidity with which the sewage diffuses into salt water are fairly well established, and have been set out in analytical form by engineers of the Los Angeles County Sanitation Districts in a discussion published in the *Proceedings of the American Society of Civil Engineers* for May, 1929.

Sewage discharged below the surface of ocean water will, because it is lighter than the salt water, tend to rise by gravity immediately to the surface of the salt water. The rapidity with which it rises from the larger outlets is evidenced by a boiling field of sewage which usually appears directly over the outlet.

Sewage discharged from an outlet pointed directly upward will rise in the form of an inverted cone, the cross section of the cone expanding as it nears the ocean surface. Our tests showed that the diameter of the base of the cone at the surface was equal to about one-third of the distance from the point of discharge under water to the ocean surface. Sewage discharged horizontally under sea water will rise to the surface of the sea water along a path resembling the curve of the path of a stone thrown horizontally, except that the curve is inverted. For this case, as before, the cross-sectional area of the curved sewage column or cone expands as the surface of the salt water is approached, and the area of the column or cone at the salt water surface is equal to about one-third of the length of the path traveled from the outlet to the surface.

During its rise from the outlet to the ocean surface, the sewage obtains what is termed its initial dilution. By this is meant its first mixture with salt water before it comes into sight at the ocean surface. This dilution remains constant for constant conditions of discharge.

As soon as the mixed sewage and sea water has reached the ocean surface its tendency is to spread laterally over the surface in all directions. During the process of spreading, it mixes with sufficient sea water to give it what is termed its final dilution. The term stratification is used to define the action of the mixed sewage and sea water floating on top of the ocean water. It does this because it is lighter and, following the law of gravity, it con-

[1] *Presented at Second Annual Meeting, California Sewage Works Association, Oakland, October 9, 1929.*

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tinues to float until such time as it has mixed with sufficient sea water to so increase its specific gravity that it will mingle intimately with the sea water underneath. The thickness of this floating sewage field remains fairly constant and is equal to about $^1/_{12}$ of the distance from the sewage outlet to the ocean surface.

Dilution is most rapid during the rise of the sewage from the outlet to the ocean surface and is dependent upon the surface area of the rising column or cone of sewage exposed to the surrounding sea water. The degree of dilution from a given orifice or outlet therefore depends upon three factors—depth, direction and quantity of flow. Since initial dilution is such an important factor in determing the field area, the depth, direction and quantity from a given orifice should be carefully considered in the design of an outlet.

To obtain high initial dilution with a given quantity of sewage and a given depth of sea water at the point of discharge, it is advantageous to discharge the sewage from the outlet laterally, as nearly horizontal as possible, thus increasing the length of the column or cone. The use of multiple outlets is advantageous, but in the use of multiple outlets it is necessary to avoid the error of so spacing them that the rising columns of sewage will mingle or conflict before reaching the ocean surface. Should the columns merge below the ocean surface, the surface area of the columns in contact with the clear salt water is reduced and the initial dilution correspondingly decreased.

The benefit of multiple outlets is well demonstrated by experience with the new Long Beach city outfall. Following the study by the Los Angeles County Sanitation Districts of the behavior of sewage in sea water and the efficiency of multiple outlets, Long Beach engineers placed over the new Long Beach outlet, discharging into the harbor entrance, a four outlet diffuser cap. Prior to placing the cap and while sewage was being discharged vertically upwards from a single outlet a bacteriological survey showed an area of 342 acres polluted to 100 *B. coli* per cubic centimeter. Six surveys following the erection of the cap showed an average of 127 acres contaminated to the same extent. The areas enclosing 10 *B. coli* are not compared because the 10 line extended beyond the limits of the first survey.

The importance of initial dilution is demonstrated by a comparison between the old Long Beach outlet and the present Hyperion outlet. The former produced a field approximating 50 acres per cubic foot per second for an initial dilution of 2 (*i. e.*, 1 part of sewage to 1 part of sea water); the latter produced a field approximating 5 acres per cubic foot per second for an initial dilution of 14 (*i. e.*, 1 part of sewage to 13 parts of sea water). Other conditions being equal, it can be said with a fair degree of certainty that the area of a sewage field varies inversely with the square of the initial dilution.

Upon reaching the surface of the salt water, the mixed sewage and sea water, as has been stated, spreads laterally, if unrestricted, in all directions, and during this spread dilution continues, but much more slowly than during the period of initial dilution. The partially diluted sewage continues to float or stratify until the specific gravity of the mixture is so nearly the same as that of the clear sea water underneath that the two fluids mingle. The outer limits of the field are marked by the location of such intermingling.

The effect of an ocean current is to elongate the field in the direction of the current. Those who are familiar with outlets along the Pacific Coast have probably observed at times the elongated segmental shape of sewage fields. This is due to the fact that the sewage in spreading over the ocean surface pushes its way against the current as far as it has the power to do so, and there stops in a well-defined visible line, the force of the spreading sewage and the force of the ocean current being equalized at such a line. The spread of the sewage is, however, greatly facilitated in the opposite direction and consequently the field moves out rapidly with the current, constantly spreading laterally across the current. This action of the two forces results in a roughly segmental field which can be shown mathematically to occupy about the same area as a circular field resulting from discharge into calm, quiet water. The distance of travel from the outlet is, however, much greater, being the sum of the velocity of the ocean current and the velocity of the spreading sewage. This feature is to be reckoned with in design.

Discharge of sewage into a narrow confined channel will result in a larger field than is produced by a similar discharge into the open ocean. The sewage field being approximately constant in depth on the ocean surface must absorb sea water along its plane of contact with the pure sea water underneath, and, whenever the depth of the field equals the depth of the sea water, dilution will cease until a further supply of sea water is available. It must, therefore, move out from its shallow location to where it can again find its stratum above the sea water, in order that dilution may continue. Under these conditions the sewage field will probably move out in a long streamer because it has lost its initial lateral velocity, and will tend to remain in an elongated field rather than to spread laterally.

A choppy, rough sea undoubtedly assists in mixing the sewage and sea water, provided the stratum of mixed sewage and sea water is not too thick. Sea traffic will also in some measure increase dilution, although this factor is not very important. Type of pretreatment of the sewage prior to discharge into the ocean has important bearing upon the field appearance and, if it is possible to remove a large percentage of the grease from the sewage, such treatment should most certainly be installed in order that the visible sleek field may be minimized.

The criterion for design at a given outfall site should comprise a calm sea surface at lower low tide coupled with the peak flow of sewage and the most pronounced effective ocean current observable at the selected site. These three conditions under proper combination will probably result in the maximum field obtainable or the maximum distance of sewage travel from the outfall site. By careful observation of the direction and intensity of the ocean currents, the available depth at the outfall site, and proximity to shores which would suffer from contamination, as well as proximity to open ocean waters, it is felt that the designer may equate the factors of depth, direction and quantity so as to erect an outfall with a field of predetermined area and distance of travel.

[*Editor's Note:* Messrs. A. M. Rawn and H. K. Palmer published a detailed engineering and mathematical treatise on this subject in *Proc. American Society of Civil Engineers*, **55,** pp. 1167–1191 (May, 1929) entitled "Pre-determining the Extent of a Sewage Field in Sea Water." This paper was discussed in the same journal in December, 1929 (pp. 2705–2707), by Harrison P. Eddy.

Mr. Eddy, to apply the author's theory, studied the results of some tests made at the Nut Island Sewer Outlet in Boston Harbor in 1915. The observed degree of dilution was derived from the free ammonia content of samples collected at various points. He calculated the initial dilution from the free ammonia content of the sewage, the surface of the harbor above the outlet, and the harbor water outside path of sewage from the outlet. From these, the initial dilution was found to be 11. The dilution near outer limit of the sewage field was found to be 83. The rate of discharge was approximately 1,380,000 gallons per hour, and depth of water over outlet about 30 feet.

Observed and computed values were as follows:

	Computed by Eddy from Analyses	Computed by Rawn's Equations
Initial dilution, volumes	5	11
Time of travel from head of rising column to edge of field	2 hr.	1.5 hr.
Distance of sewage travel with current	4810 ft.	1400 ft.

Another comparison was made based on analyses at the New Bedford outfall. Dilutions computed from analyses were 15 for August 9, and 111 for Sept. 24, 1915; the Rawn equation gave a dilution of 9 volumes. In this case the dilution computed by the Rawn equation was well on the side of safety.

Mr. Eddy concludes that "caution must be exercised in using formulae for predetermining the extent of a sewage field in sea water, although they may be well used as guides to judgment."]

Vacuum Degasification of Imhoff Tanks at Texas A. & M. College

BY E. W. STEEL[1] AND P. J. A. ZELLER[2]

During the past year much interest has been manifested in Texas and elsewhere as to the possibilities of increasing the efficiency of Imhoff tanks by applying a partial vacuum to the gas vents. Accordingly, it was felt that investigation of the matter at the Sewage Research Laboratory of the Texas Engineering Experiment Station at the A. & M. College would be of value.

Bottle experiments were first tried. In these seeded raw sludge was placed in bottles, one of which was kept at atmospheric pressure as a control while the other was held under a partial vacuum equal to 1.15 in. of mercury or 0.56 lb. per square inch. Observations and tests of the sludge were made over a period of one month with inconclusive results. It was felt that to give the process a fair trial it should be tried on a plant scale.

The Imhoff tank at College Station has two units of equal size with sludge digestion chambers, gas vents and flow chambers completely separated. The influent channels are so arranged that the sewage can be divided equally, each half going to a unit. By applying a partial vacuum to the gas vent of one unit, the effluent could be observed and compared with the effluent of the other unit as a control.

The walls of one gas vent were raised to a height of 4.5 feet above the flow line and a steel plate was bolted on to form a cover. Sampling pipes and scum agitators were placed and so sealed that gas could not leak inward or outward. The gases evolved by sludge digestion were exhausted by means of a Connersville blower into a holding tank. It had been planned to measure the amount of gas evolved but this was prevented due to corrosion of the gas meter by the wet gas.

The amount of partial vacuum obtained under the hood was regulated by means of a float switch which started the blower when the gas evolved had raised the pressure under the hood. When the blower had exhausted the gases and lowered the pressure to a predetermined point, the float switch disconnected the motor until the pressure again increased. The throw of the switch necessitated some fluctuation in the pressures beneath the hood, the partial vacuum generated varying from a maximum of 3.7 feet of water to 1.75 feet, with an average value of 2.55 feet, corresponding to gage pressures of about −1.6 lb., −0.7 lb. and −1.1 lb., respectively.

Speculations and claims regarding the effect of vacuum degasification

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had been directed toward its possible effect upon odor production, sedimentation and sludge digestion. It was felt that a series of determinations of the hydrogen sulphide content of the effluents from the degasification and control units would throw light upon the matter of odors; that the reduction in suspended solids and biochemical oxygen demands would testify as to the effects upon sedimentation; and that sludge analyses would indicate the effect upon sludge digestion. Prior to the beginning of the experiment, the sludge was so manipulated that the contents were uniform in condition and amount in each hopper of both tanks.

For a period of one month daily samples of raw sewage and the effluents of the degasified and control units were collected and the hydrogen sulphide content, suspended solids and biochemical oxygen demands were determined. In addition to the daily samples, during one 24-hour period, hourly samples were taken and similar determinations were made. Sludge samples were collected at weekly intervals at a point one foot below the sludge level and were analyzed for solid content, ash and biochemical oxygen demand. The scum in the gas vent of each unit was thoroughly agitated once daily. There was no undue scum formation or lack of it in either unit.

The determinations indicated that vacuum degasification exerted no great effect, good or otherwise, upon the hydrogen sulphide content, suspended solids or biochemical oxygen demand of Imhoff tank effluent. The hydrogen sulphide showed considerable fluctuation in both tanks, the average of all determinations being a 7.05 per cent increase for the control unit as compared with 8.96 per cent increase for the degasified unit. The suspended solids showed less fluctuation throughout the test than did the hydrogen sulphide, the average being 53.5 per cent reduction for the control unit and 50.5 per cent reduction for the degasified unit. The average of the biochemical oxygen demands indicated a 36.1 per cent reduction in the control unit and 35.6 per cent reduction in the degasified unit. Table I shows the data obtained from the daily samples. The hourly samples taken over a period of 24 hours showed no special significance and are not included.

It was considered possible that the varying pressure in the closed gas vent of the degasified tank was responsible for the fact that in hydrogen sulphide content, B. O. D. reduction and suspended solids reduction, the degasification process produced an effluent slightly inferior to that of the control unit. The evolution of gas between the time at which the blower stopped until it resumed operation displaced each hour a volume of supernatant liquid from the digestion chamber equal to approximately one-tenth of the sewage passing through. Tests made of the supernatant liquid showed no considerable difference between it and the sewage in the flow chamber and consequently the interchange could have had no appreciable effect.

TABLE I

EFFECT OF DEGASIFICATION UPON TANK EFFLUENT

All results in per cent reduction or increase

Date Feb., 1929	Hydrogen Sulphide Removal (Compared with Raw Sewage) Control	Degas.	Suspended Solids Reduction (Compared with Raw Sewage) Control	Degas.	B. O. D. Reduction (Compared with Raw Sewage) Control	Degas.
7	+66.0*	−91.0	83.7	83.7	59.1	75.6
13	−42.0	−16.0	59.0	−34.3	−20.2	−50.7
14	−52.0	−39.0	50.8	28.7	−18.7	−54.2
15	−167.0	−483.0			41.4	50.0
18	0.0	9.8	69.5	60.3	32.7	66.3
19	35.0	29.0	98.0	49.8	44.5	41.2
20	−11.5	−19.0	43.6	43.3	28.6	27.1
21	−30.0	−16.0	62.5	64.6	5.8	−15.9
22	5.2	−24.0	26.9	47.7	− 8.2	13.3
23	−33.0	3.2	21.2	35.0	29.6	23.5
25	−296.0	−25.0	48.7	60.6	33.7	35.8
26	26.0	35.0	34.9	44.8	− 2.4	1.2
27	27.0	−19.0	−16.8	−16.2	64.2	64.2
28	63.0	4.3	7.2	42.7	45.8	49.6
Mar.						
1	10.0	48.2	51.9	50.0	14.1	21.1
2	−74.0	−397.0	54.4	39.9	26.8	31.7
4		31.0		59.6	46.2	46.2
5	64.9	64.9	29.1	50.0	44.8	40.5
6	− 4.3	11.6	53.5	49.1	40.6	45.1
7	−27.8	− 3.8	55.1	48.8	31.7	26.0
8	−47.2	−36.1	67.0	63.0	43.3	28.9
9	−19.6	−13.7	65.2	39.4	57.2	41.2
11	88.7	36.4	65.8	68.3	57.2	53.9
13	−30.3	−12.1	50.0	41.0	14.1	3.8
14	13.9	2.8	54.0	47.3	27.8	34.0
15	−42.9	2.9	57.8	52.2	43.3	40.8
Average	− 7.05	− 8.96	53.5	50.5	36.1	35.6

* Minus signs indicate increase.

The sludge analyses were more interesting than the other determinations. Table II shows the results obtained. The averages of the determinations are slightly favorable to degasification. The biochemical oxygen demand of the degasified sludge is 4.7 per cent less than that of the control unit. The demand of the degasified sludge is also very slightly less than that of the control unit when based on per cent of solids or per gram of volatile matter. This indicates that the degasified sludge may have been in somewhat better condition than the sludge from the control unit.

It should be noted that the biochemical oxygen demand fluctuated considerably in the sludge of the control unit but was far more constant in sludge from the degasified unit. The sludge samples were collected alternately from each of the two sludge hoppers of both units. It would

TABLE II

SLUDGE RECORD

Date	pH	Solids, %	Ash, %	B. O. D., p.p.m.	B. O. D. per Per cent Solids	B. O. D. per G. Volatile Matter
Control						
Feb. 22	7.2	10.60	51.2	725	68.4	140
Mar 1	6.8	7.90	50.1	857	108.0	216
8	7.1	9.21	49.1	750	81.5	160
15	7.1	8.53	49.7	910	107.0	213
22	6.8	8.39	49.6	690	82.3	163
28	7.0	8.75	41.3	590	67.5	115
Apr. 4	6.9	9.57	50.3	625	65.4	132
11	7.0	6.22	47.9	650	104.0	200
18	7.0	9.22	51.3	570	61.8	127
Averages	7.0	8.71	48.9	707	83.0	163
Degasified						
Feb. 22	7.2	9.28	44.6	880	94.8	171
Mar 1	6.8	8.00	45.2	565	70.7	129
8	7.1	7.85	44.7	755	96.2	174
15	7.0	6.79	45.2	635	93.5	170
22	6.9	8.52	45.2	670	78.7	143
28	7.1	7.80	45.5	595	76.3	140
Apr. 4	6.9	8.16	45.3	530	65.0	119
11	7.1	7.64	46.6	690	90.3	169
18	7.0	9.11	46.7	680	74.6	140
Averages	7.0	8.13	45.4	667	82.2	151

appear that in the control unit digestion was taking place at an uneven rate. This might have been due to slightly greater accumulations of solids in one hopper than in the other. A possible explanation of the more uniform digestion in the degasified unit is that the fluctuation of liquid level in the gas vent tended to set up currents which had a gentle mixing effect upon the sludge. This condition was found to be somewhat beneficial in studies at the New Jersey Sewage Research Laboratory.

Of interest also are the pH values of the two sludges. The statement has been made that vacuum degasification would quickly remove carbon dioxide from the digesting sludge and thereby favor the digestion process. While this statement is open to attack on various grounds, it is apparent that carbon dioxide exhaustion is not obtained to any great extent or it would be reflected in the pH values obtained.

Conclusion

For a period of five weeks controlled observations were made of the effect of application of a partial vacuum to the gas vent of an Imhoff tank. The results showed no appreciable effect, beneficial or otherwise, in re-

duction of hydrogen sulphide content, suspended solids or biochemical oxygen demand. Observations of the sludge over a period of sixty days indicated a very slight benefit in digestion, a possible explanation for which is that the currents caused by the varying vacuum resulted in a gentle agitation of the upper sludge levels.

Effect of Degassing on Bacterial Count of Sewage Sludge.—A laboratory experiment was made by R. G. Upton, of Stephen F. Austin State Teachers College, Nacogdoches, Texas, in an attempt to determine whether or not the degassing of "sewerage" causes changes in the bacterial flora. Samples of sludge were collected somewhere, source or type of sludge not stated, and allowed to stand in two bottles in the laboratory for eight days, with counts made on the second, fourth and sixth days on plain agar and Wilson's agar (anaerobic). Hydrogen sulphide formers were counted as black colonies on Wilson's agar. No significant variations were noted in the counts from both samples. On the eighth day a vacuum of 12 to 18 inches of water was maintained in one bottle for six additional days, with counts as before after two, four and six days. No differences were found in the counts of anaerobes and hydrogen sulphide formers, but there was immediately a large increase, from 290,000 to 750,000 per cc., in the plain agar count of the degassed sludge. The counts per cc. during the comparative tests were as follows:

Days	Degassed	Quiescent
0	750,000	130,000
2	250,000	40,000
4	170,000	20,000
6	175,000	30,000

No explanation is offered for the difference in results, and data of check experiments, if any, are not offered. The author recommends further study of different kinds of "sewerage."—*Proc. Eleventh Texas Water Works School*, pp. 152–153, 1929.

Sewage Works Operation

Springfield, Illinois, Sewage Works Laboratory

A Model for a Medium Sized Sewage Works

By C. C. Larson[1] and H. F. Ferguson[2]

A sewage treatment works to be intelligently, efficiently and economically operated must be under laboratory control. For very small sewage works, local laboratory provision is warranted for only a few simple control tests, supplemented by analyses made at commercial or state maintained laboratories. For a sewage works the size, cost and importance of that of the Springfield (Illinois) Sanitary District[3] a fully equipped laboratory was considered by the District Board and the consulting engineers to be very essential. Because this laboratory is located at the capital city of Illinois it was further considered to be an ideal location for a model sewage works laboratory. Therefore time, thought and effort were given toward planning and equipping the laboratory to make it as efficient, convenient and serviceable as possible without including anything that might be regarded as unnecessary or in the nature of a luxury. It is believed that this laboratory is decidedly better than the average sewage laboratory and at least the equal of any sewage works laboratory of its size in Illinois or any that have been inspected in other states.

The laboratory occupies two well-lighted rooms on the second floor of the administration building. The rooms measure 17 × 19 feet and 12 × 19 feet, giving approximately 550 square feet of floor space. The general arrangement of the rooms and equipment is shown in accompanying pictures. The larger room was designed for routine chemical analyses and the smaller room for bacteriological work and special research problems. The door jambs and woodwork are finished in dull black and the doors in silver gray to match the furniture. The floors are a buff-colored plastic composition.

The laboratory furniture was built and installed by the Kewaunee Manufacturing Company of Kewaunee, Wisconsin. It is constructed

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[2] *President, Springfield Sanitary District, and Chief Sanitary Engineer, Illinois Department Public Health.*

[3] Descriptions of the sewage works may be found in the 42nd Annual Report of the Illinois Society of Engineers, page 77, and in the proceedings of the Illinois Association of Sanitary Districts, May, 1929. An illustrated descriptive pamphlet can be obtained from the authors upon request.

of oak with a clean, pleasing silver-gray natural finish, except the bench and table tops, which are of $1^5/_8$-inch laminated birch, finished with an acid-proof black surface. The drain boards and the bench top in the Kjeldahl digestion hood are of albarene stone.

All benches rest upon pedestals three inches high with the flooring coved to the pedestals. The lower ends of table legs are protected with 3-inch aluminum shoes. These pedestals and shoes and wall-hung radiators permit the entire floor to be quickly and easily mopped.

The arrangement of cupboard and drawer space is shown in the accom-

FIG. 1.—Routine Chemical Analysis Room, Showing Center Bench, Kjeldahl Digestion Equipment, Wall Cabinet, Desk and Doorway to Bacteriological and Special Analysis Room.

panying photographs. All benches and tables are equipped with outlets for gas, water, electricity and air under pressure or vacuum. Electric outlets for bench use are located in the walls above the benches while all others are mounted directly on table tops. Sinks are of one-piece ceramic construction and each is provided with one cold and one hot-and-cold water mixing faucet. All plumbing fixtures, gas and air outlets are chromium plated. Waste pipes and traps are of Duriron.

In addition to good natural lighting by windows, the rooms can be lighted by ceiling globes which are of blue daylight glass in order to permit accurate comparisons in colorimetric determinations.

A brief description will be given of some special or unusual features not found in the average laboratory.

A dumb waiter, shown in one picture between the electric stove and water still, was installed for raising and lowering samples and empty sample bottles from the ground floor to the laboratory, thus making for convenience to the plant operators and avoiding the tracking up of floors, corridors and stairs. It has proved satisfactory and valuable. The carrier has two shelves and will accommodate 12 one-gallon bottles. On the ground floor is an electric refrigerator for storing 24-hour composite

FIG. 2.—Routine Chemical Analysis Room. In Foreground Center Bench with Suction Filters, Muffle Furnace and Drying Oven; in Background Water Still, Dumb Waiter, Hood and Kjeldahl Digestion Equipment.

samples during the period of collection. This also contains a water coil for cooling drinking water for the operators and workmen.

The walls back of all benches are faced with ivory-colored tile to a height of 18 inches above the bench tops. This facilitates cleaning and avoids damage to the walls in case of accidental spilling of reagents and solutions. The remainder of the walls are of buff-tinted gypsum plaster.

The wall cabinet built in the partition between the two rooms is provided with double glass doors opening into both rooms so that the glassware and chemicals stored therein are easily available from either room. In the base of this cabinet is a drawer 66 inches long which will accommodate standard 5-foot lengths of glass tubing.

Under the hood is a Kjeldahl digestion fume duct of Duriron which connects with an acid-proof exhaust fan located in the attic. The fan draws both on the fume duct and the hood interior and is of such capacity that doors were not required in front of the hood. A switch with pilot light is located in the top of the hood for operating the exhaust fan. Under the hood also is an electric water bath constructed of monel metal. This is easily cleaned and does not become corroded and discolored as does the ordinary copper bath.

The small horizontal autoclave is constructed from an acid-resisting alloy known commercially as Ascoloy. The metal takes a high polish

FIG. 3.—Routine Chemical Analysis Room, Showing Chemical Case, Balance Table, Ammonia Still and Center Bench.

and does not become dull under the action of laboratory fumes. A Hotpoint electric range is used for cooking media and the oven is used for sterilizing bacteriological glassware.

An electric refrigerator is used for storing samples and media. In the picture the door has been left open to show the special 20-degree incubator for B. O. D. determinations. This incubator was built of transite board to fit the space. A bubbler fountain on one end of the refrigerator furnishes cooled drinking water for laboratory and office personnel.

The water still and storage tank as well as the ammonia still mounted on the wall are chromium plated and are heated by electricity. The water

still was made by the Precision Scientific Company and has proved especially valuable because it delivers water entirely free from ammonia.

The tall cabinet of small drawers (each $2^1/_2 \times 11 \times 14$ inches) was specially planned for storing separately the various sizes of rubber stoppers, corks and rubber tubing. Each drawer is provided with a name plate.

The low table in the center of the bacteriological room was designed for a microscope table and has a built-in microscope lamp near one edge. This consists of a light and reflector under a three-inch square frosted glass plate which is mounted flush with the table top. The light is operated

FIG. 4.—Bacteriological and Special Analysis Room, Showing Microscope Table, Wall Bench with 37° Incubator and Refrigerator with 20° Incubator. A Tall Cabinet of Small Drawers Located at the Extreme Left Is Not Shown in the Picture.

by a toggle switch at the edge of the table. Two small cupboards are provided in a pedestal under the center of the table for storing microscopes.

The bench in one of the rooms has two shallow, wide drawers for storing burettes. These drawers are wide enough to accommodate a standard 100-cc. burette and notched wooden rails are mounted on the bottoms to keep the burettes separated and to prevent breakage.

Above each sink is placed a 2-gallon aspirator bottle for ammonia-free water, a notched wooden rack carrying six standard pipettes and a liquid-soap dispensor filled with 2.5 per cent carbolic acid.

Electricity is used for all laboratory equipment where heat or power is required, even to the extent of the wall clock, which is an electric Telechron. Because of a well-managed and efficient municipal electric plant, electricity is obtained at the low rate of about 0.9 cent per kilowatt hour. Provision was made, however, for the future substitution of gas for heating purposes in the event that the gas produced by the digestion of the sewage sludge becomes available in sufficient quantities to exceed building and sludge-heating demands and such use of gas would make a worthwhile saving or be desirable for any other reason.

The slight added cost of the chromium-plated and special acid-resisting fixtures and equipment has been more than justified by the minimum attention required for keeping them clean and bright and by the smart, neat appearance they give to the laboratory. This is especially significant in a sewage works laboratory where the atmosphere usually contains considerable hydrogen sulphide. Copper and nickel are quickly attacked and require much labor and time to be spent in polishing in order to keep them clean and bright. Monel metal and chromium plating, on the other hand, require only an occasional wiping off with a damp cloth to keep them in first class condition.

The approval and coöperation of Sidney S. Breese and George T. Cresse, trustees of the Springfield Sanitary District, made possible the planning and equipping of this laboratory. Credit is also due to the consulting engineers, Pearse, Greeley and Hansen, and District Engineer W. B. Walraven for coöperating in the planning of the second floor of the administration building to provide ample and convenient space for the laboratory rooms. The sewage works contractors, Bierd, Lydon and Grandpre, also coöperated, and the Kewaunee Company was very helpful in working out detailed plans for the laboratory furniture, based upon general plans and specifications submitted to them by the authors.

Laboratories of the North Side Sewage Treatment Works of the Sanitary District of Chicago

BY JOHN R. PALMER[1] AND F. W. MOHLMAN[2]

Modern sewage treatment works of the size and importance of the North Side Treatment Works of The Sanitary District of Chicago require comprehensive and convenient laboratory facilities. Consequently, in planning and installing this laboratory all facilities were included which were considered to be essential for chemical and bacteriological analyses of sewage, effluents and sludges; for chemical analyses of coal, oils and plant materials; for research on all phases of sewage treatment; and for experimental work on a larger scale than is usually possible in plant laboratories.

The experience gained in installation of our Main Laboratory, Des Plaines and Calumet Laboratories, and some seven or eight field laboratories was of value in determining the selection of equipment and apparatus which had stood the test of time and continuous usage in the laboratory work of the Sanitary District.

The North Side laboratories are located on the third and fourth floors of the central tower of the administration building. This tower, which is 49 ft. by 61 ft. in plan, is four stories high while the wings of the building are each two stories in height. The laboratories therefore have light on all sides. There is an excellent view of the plant from the laboratory, the north windows overlooking the aeration tanks, with the operating galleries and final settling tanks in the background.

The main chemical laboratory is located on the fourth floor and the bacteriological laboratory, the coal and oil laboratory and an experimental laboratory on the third floor (Figure 1). A well-equipped first-aid room is also located on the third floor adjoining the bacteriological laboratory.

Laboratory Furniture and Equipment

Detailed design of cabinets, benches, tables and hoods is hardly necessary for the furniture and equipment of a modern laboratory inasmuch as various laboratory furniture manufacturers can supply a large variety of standard bench sections, tables and hoods to meet almost any requirements. The wall benches and tables, the center work benches and the hood for the North Side Laboratory were selected from standard sections made by the Kewaunee Company.

With the exception of the table tops, the exposed surfaces of the laboratory furniture are of kiln-dried oak, finished in silver-gray. This is a

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[2] *Director of Laboratories, The Sanitary District of Chicago.*

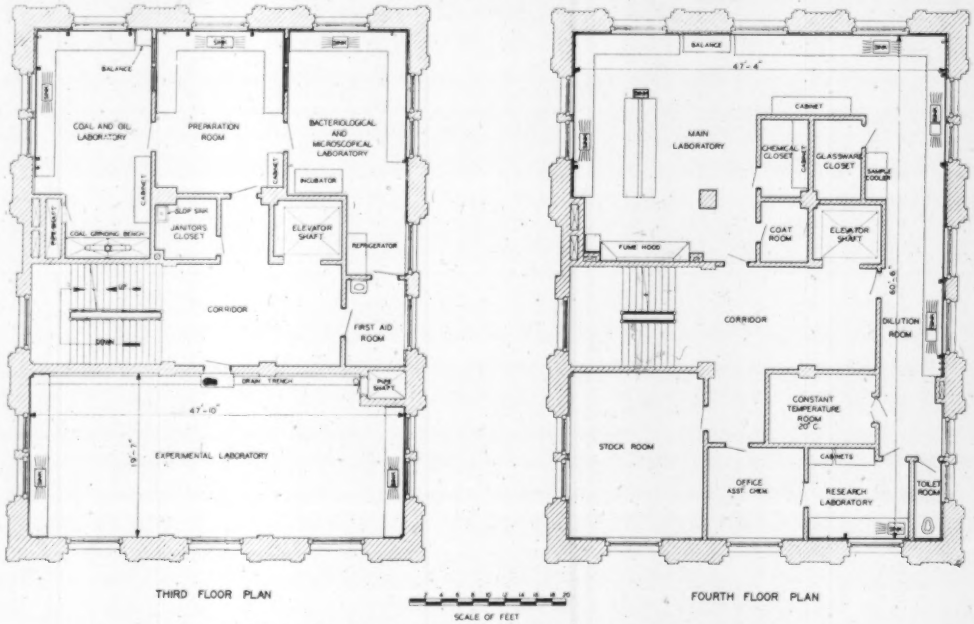


FIG. 1.—North Side Sewage Treatment Works, Main Building. Floor Plan of Laboratories.

pleasing and serviceable finish for laboratory use. It is not so light that it will become dirty quickly, but it is lighter and more effective than the usual brown varnish finish. The specifications for the finish were as follows:

"First sponge surface with cold water and when dry sandpaper perfectly smooth. Apply one coat Pratt and Lambert's silver-gray acid stain or equal, and when dry sandpaper lightly. Fill with white paste filler. This should be followed with one coat of white alcohol shellac and three coats of spar varnish, rubbed between coats, the finished coat to be rubbed with pumice stone and oil."

The table tops are made of birch $1^5/_8$ in. thick, built up of strips not over 3 in. wide and glued with a V-joint under heavy pressure. The tops are bolted together with a concealed spring bolt running through the top from side to side to prevent opening of the glued joints. The backs of the table tops are finished off with a 4-in. backboard of the same thickness as the table tops. Both tops and backboard are finished with the usual black acid-proof coat, applied in two solutions, one containing cupric chloride and potassium chlorate, the other anilin hydrochloride, followed by a heavy coat of linseed oil.

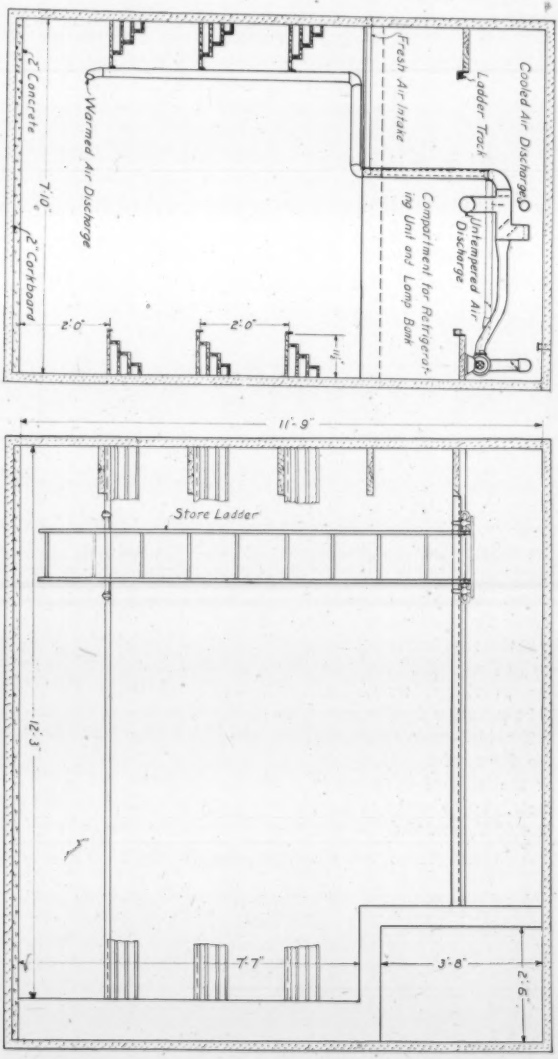
Although alberene table tops are usually used in university laboratories, the preference of practically all of our chemists is for wood tops.

The laboratory sinks are made of one-piece construction acid-proof stoneware. The sinks for general use are 24 in. by 18 in. and 8 in. deep. A special sink was made for use in the dissolved oxygen and B. O. D. determinations. This is a double sink, one side of which is 24 in. by 18 in. and 5 in. deep, draining into a deeper section 18 in. square and 10 in. deep. The shallow section of this sink is very convenient when adding the different reagents for the dissolved oxygen determination. Drainboards for the sinks are made of wood similar to the table tops which they adjoin and are fluted with a pitch of $^5/_8$ in. to the sink on all sides.

Gas, air, vacuum and electrical outlets are located at convenient points at the back of the table tops. The plumbing and all other fixtures are chromium plated. Because of the corrosive nature of the laboratory wastes the waste lines are made of 2-in. extra-heavy lead pipe. A drum trap of extra-heavy lead, so constructed that the wastes come in contact with no other metal, is used to trap each sink. All of the joints in the waste lines are burned with lead.

Constant Temperature Room

The feature of the North Side chemical laboratory is the elaborate constant temperature (20° C.) room. This room was desired because of the large amount of B. O. D. work usually in progress, and was made of ample capacity so that several chemists could work in the room if necessary (Figure 2).



Cross Section

Longitudinal Section

FIG. 2.—Constant Temperature Room.

The room is 8 ft. by 12 ft. in plan, inside the 2-in. cork-board, 1/2-in. cement walls and ceiling. The working height is 11 ft. 9 in. except under the chamber for temperature control and air-circulating mechanism, where the height is reduced to 7 1/2 feet. The floor is insulated with 2-in. cork-board, over which is laid a cement floor to a true level, covered finally with 1/4-in. corrugated rubber matting.

A motor-driven refrigerating machine is installed in the basement for cooling calcium chloride brine, which is pumped up to the 20° room and circulated through the cooling coils, which are contained in an insulated box suspended inside the room over the door.

The room is cooled or warmed by air, which is circulated by a constant-speed blower. The air passes through copper ducts to outlets for warmed air at the bottom and for cooled air at the top of the room. When the temperature is 20° C. ± 0.25°, the air is neither cooled nor warmed and is discharged at the top of the room. The rate of pumpage displaces the contents of the room in approximately 15 minutes.

There are two thermostats in the room. One controls the heating of air, which is accomplished by throwing into circuit five carbon filament lamps for 0.25° C. drop in temperature, or fifteen lamps for 0.50° C. drop. The same thermostat controls cooling by operating dampers, in the ducts, which divert the circulated air through the chamber which contains the coils through which the brine circulates, at the same time turning off the heating elements. The other thermostat controls the circulation of brine through the coils in the closed chamber; when these are by-passed the brine continues to circulate through the sample cooler and refrigerator, described below. When more cooling is required for the 20° room, the brine again passes through the coils in the chamber.

Shelves are built in tiers along the sides and end of the room, extending up to the ceiling. Ladders run on overhead tracks on both sides of the room, giving access to the higher shelves. A ceiling light and a reel-light extension furnish ample illumination.

Two high-grade recording thermometers have been used for determining the degree of variation of temperature. One has been placed on a shelf at the back of the room, and the other at the front. Temperatures recorded continuously for a week or longer show a variation of less than ± 1.0° Fahrenheit.

Sample Cooler

A sample cooler was built in the main laboratory, near the entrance from the elevator. This cooler is used for storage of samples over night or when not in process of analysis. The cooler is an insulated box 5 ft. by 2 1/4 ft. in plan and 6 1/2 ft. high, inside dimensions, with double refrigerator doors having no center post. There is one shelf 4 ft. from the

floor. The four-wheeled, two-shelved cart, on which the samples are moved around the laboratory, can be run directly into the cooler, thus obviating the necessity of transfer to refrigerator shelves.

The sample cooler and a refrigerator on the third floor in the bacteriological laboratory are cooled by the circulating brine pumped from the basement.

Experimental Laboratory

The experimental laboratory on the third floor was designed for convenience in installation and operation of small-scale experimental devices which are too large for the chemical laboratory and too small to be placed outdoors. The value of this laboratory has already been demonstrated.

Pipe lines for sewage, activated sludge, gas, air, vacuum and water are suspended from the ceiling. These lines run the length of the room and are made up with plugged tees every five feet. The sewage and sludge are lifted from the basement of the building by means of centrifugal pumps which are operated by push buttons located in the laboratory. Electrical outlets of sufficient capacity to operate any experimental equipment are located at various points in the room. These features make it very convenient in setting up experimental apparatus. The floor is of concrete and is pitched to a drain trench so that it can be washed down with a hose.

At present a 3-ft. diameter by 2-ft. face Oliver filter has been installed in this room for experimental work on sludge filtration. A Wallace and Tiernan chlorine-control apparatus with a capacity of 10 lb. per 24 hr., formerly used at our Des Plaines plant, is to be installed for research on the chlorination of sewage and sludge. Other devices and models, built on a small scale, have been set up and operated in this room.

Convenience in Routing Samples for Analysis

The layout of the chemical laboratory on the fourth floor was designed to afford the maximum convenience in routing the samples through the laboratory for routine analyses. The composite samples, unchloroformed, are brought up the elevator and placed on the sample cart, which is wheeled into the cooler, if analysis is not to be started immediately. In starting the analysis the samples are first brought into the dilution room of the main laboratory, where the dissolved oxygen and B. O. D. determinations are to be made. Here eight-ounce samples are siphoned from the gallon bottles. From these smaller sample dilutions are made for the B. O. D. determination. The 20° C. constant temperature room, in which the dilution bottles are incubated, is adjacent to the dilution room and but ten feet from the sink at which the dilutions are made. The convenience in having the constant temperature room so close to the dilution room is apparent, especially when large numbers of incubation bottles are set up.

After removing sufficient sample for the B. O. D. determination the samples are chloroformed and wheeled into the main laboratory where the

FIG. 3.—Chemical Laboratory, Showing Ammonia Still, Fine Balances, Titration Bench and Ovens.

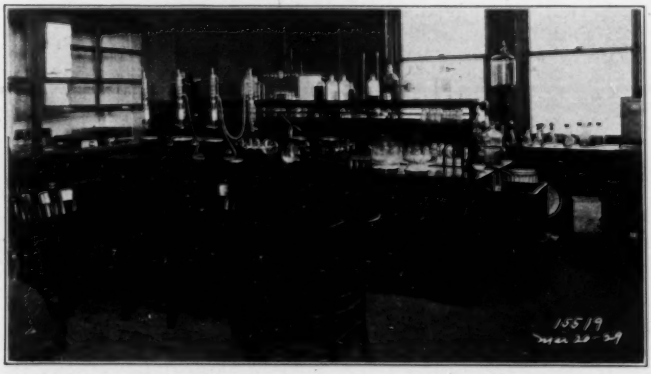


FIG. 4.—Chemical Laboratory, Showing Center Work Bench, Hood and Table.

remainder of the analyses are run. At a sink which is centrally located on the west wall, samples are taken out for the different analyses. Vacuum connections on the table adjoining the sink are used for the Gooch crucible

filtrations for suspended matter. Reagents for the Kjeldahl digestion are also convenient to this sink. The hood is on the south wall of this room, some 15 ft. from the sink. It is divided into two sections, one being fitted for general work with a water bath and hot plate, while the other side is equipped with two Duriron digestion tubes for Kjeldahl digestions, each with 10 nipples, double-decked to conserve space. A fan is installed in the draft tube, with dampers controlled from the floor.

Table space is provided along the north wall for reading Nessler tubes. A 12-burner still for ammonia distillations is mounted on this wall to the right of the space used for tube work (Figure 3). A center table 12 ft. long and 4 ft. wide is provided for general laboratory use. This table has working space on both sides, with a double shelf and open drain in the center and running the length of the table. The drain terminates in an open sink which is installed at the end of the table (Figure 4). Chemicals are kept in a closet, off the main laboratory, which is equipped with shelves and a cupboard. A similar closet convenient to the wash sink is also equipped with shelving and is used for storing clean sample bottles.

It will be noted that the laboratory plan provides for no separate washroom and for no fine-balance room. It has been our experience that these functions may be carried on more conveniently in the main laboratory, providing proper thought is given to the location of the wash sinks and fine balances.

The main consideration in the laboratory layout was to have equipment as convenient as possible for the routine analyses. While there is undoubtedly a personal preference in any arrangement of this kind we feel that in general our layout is convenient and practical for the particular type of work that is done in a sewage treatment works laboratory.

The North Side Treatment Works were built under the direction of E. J. Kelly, Chief Engineer, Philip Harrington, Asst. Chief Engineer, and Langdon Pearse, Sanitary Engineer. The design of the constant temperature room was worked out by W. T. MacClenahan, Asst. Engineer.

Laboratory Control of Sewage Treatment Works[1]

BY G. F. CATLETT[2]

It is impossible to operate sewage treatment works properly without a certain amount of laboratory control, or without the collecting and recording of control data, to make them perform the functions for which they are built.

Modern sewage treatment plants have only recently become necessary to any considerable extent in this state, and municipal officials have little conception of just what is involved and what is meant by sewage treatment. To most officials and to judges of our superior and even supreme court bench, treating sewage means installing a septic tank. As septic tanks for home installation have been very generally exploited with the sales statement that they may be buried and forgotten, this conception exists largely in the popular mind. The consequence is that thousands of dollars are invested in municipal sewage works, and in spite of this, lawsuits are lost on account of the ineffectiveness of the treatment. The installation of such works to prevent a nuisance is a waste of municipal funds, unless the works be properly operated, and an effective system of operation involves a certain amount of laboratory testing.

In speaking of laboratory tests for control of operation of sewage works the impression should not be gathered that a complicated system of analytical procedures, involving the services of an expert chemical analyst, is required for the comparatively small plants in North Carolina. We are all more or less familiar with the laboratory work required in controlling a water purification plant. Sewage plant laboratory work is no more complicated and in most cases much more simple than water laboratory work.

There are scores of analytical procedures that have been applied and are still applicable in sewage analysis. However, a large number are too complex and time-consuming for plant control work. Others have been superseded by simpler or more accurate tests that give the same information. Still others are applicable only in connection with certain complications that may be encountered in sewage treatment.

Even should abundant personnel be available for the work, it is much better to confine one's efforts to a few simple determinations on a large number of representative samples, rather than an elaborate series of determinations on a few samples or samples that are not typical of the effluent under average conditions.

From the list of laboratory determinations it is possible to select some that may be carried out by an operator with no technical training and

[1] *Presented before the North Carolina Sewage Works Association, High Point, November 3, 1929.*

[2] *Principal Assistant Engineer, North Carolina State Board of Health, Raleigh.*

without a plant laboratory, but which will give invaluable information in operating a small plant. Other more complex methods will require laboratory equipment similar to that with which the usual North Carolina water plant laboratory is supplied, and the services of a technical operator of like caliber. As a matter of fact when a town has a man carrying out laboratory tests in control of a water purification plant, as is usually the case in North Carolina, he is entirely competent for a complete system of sewage plant testing and his services may be extended to that field.

What tests may be profitably made, where they are applicable, and the information to be derived from them will best be made clear if we consider them in application to the various phases and component units of a treatment plant.

Laboratory Data on Raw Sewage

Sewage as received at the treatment plant is very variable in its composition. It contains the excreta, urine, kitchen and laundry wastes of the inhabitants. Though the concentration of excretal matter may vary slightly, it is generally fairly constant per capita throughout the country. The concentration of the material from these sources, however, varies greatly in different systems, depending on whether it is a combined or separate system, whether sewer pipe joints are well made and tight, whether it rains or is dry, and whether water supply is plentiful and per capita consumption high or otherwise. The quantity and concentration of sewage also varies greatly during different hours of the day and days of the week. This variation is fairly constant, in cycles, for a specific town but varies in different towns according to habits of the people, length of outfall and presence of industrial wastes. The concentration of sewage according to these variations and the typical components at the various concentrations must be determined by laboratory methods. These determinations should include total solids and the proportion of solids that are mineral and organic. In addition to a knowledge of the total quantity of solids of various kinds, we should also know the quantity of nitrogenous or animal material, and the quantity of material that will demand oxygen from the stream for its ultimate disposal. The laboratory determination of five-day oxygen demand is the best index of this latter characteristic. It is important to know the degree of staleness of the sewage, which is best indicated by free ammonia and the reaction of the sewage.

Industrial wastes greatly complicate these factors and a laboratory investigation of these should be made in detail.

The laboratory work involved in getting this information should logically be carried out before the plant is designed and the operator should get it prior to taking up the operation of his plant. Most of the determinations are simple and may be carried out with the usual equipment supplied for

operation control. The sewage laboratory of the State Board of Health is designed for service to the municipalities in studying the characteristics of the sewage to be treated. Coöperation with the operator is offered and facilities are provided in the state laboratory for making laboratory determinations for which the town is not equipped.

Laboratory Work for Routine Control of Operation

When the characteristics of the sewage are established by laboratory investigation and a plant is designed to handle such sewage, the plant laboratory work resolves itself into a routine series of tests to control and check up the operation.

Sampling.—The most important thing in connection with sewage plant laboratory work is the securing of representative samples. In water purification, raw water and various effluents of the plant vary little during the 24 hours and a random sample taken at a convenient time is sufficient. This is not true of a sewage treatment plant, as the sewage passing through the plant varies widely from hour to hour. It is not feasible, even in a very large plant, to test samples each hour, but a "grab" sample taken at random during the day will not be worth the time spent in laboratory work on it. The only satisfactory method is to secure a composite sample representing the 24-hour period, by adding a small sample taken hourly to a large sample bottle. At the end of the 24 hours laboratory determinations are made on the sample in the large bottle. To get a representative composite the quantity of small hourly samples added to the large bottle should be in proportion to the rate of sewage flow at the time the sample is taken. The large bottle should preferably be iced while sampling.

For very small plants, where it is impossible to keep a man in constant attendance, resort is had to collecting an "average hour" sample. The variation in concentration of sewage at various hours is studied and the hour selected for sampling which represents the usual average concentration. This method is very unsatisfactory and is complicated when industrial wastes are present in the sewage. It should not be resorted to if it is possible to secure composite samples, though a long series of daily test on such samples may furnish some useful information.

Where it is possible to sample only during daylight hours, results should be corrected by estimate for night concentrations.

Points of Sampling.—Samples should be taken on raw sewage (if fine screens are used sample after screening and correct for weight of screenings), tank effluent, sludge from digestion tanks, filter effluent, secondary tank effluent, stream above and stream below outfall. Where primary treatment only is applied we will need raw sewage, tank effluent, and stream samples only. In the case of an activated sludge plant frequent sampling will be required for percentage of returned sludge in aeration tank.

Raw Sewage Samples.—The function of a sewage treatment plant is (*a*) to settle out all settleable solids, (*b*) convert solids in colloidal suspension to settleable form and remove them, and (*c*) to oxidize putrescible matter in solution to stable forms before discharge into the stream. A supplementary function is disposal of the settled material.

The main reason for the collection of laboratory data on the raw sewage is to establish the amount of pollutional materials as a basis upon which to judge the efficiency of the various treatment units. We therefore want to know the amount of settleable solids, the amount of suspended solids, and the amount of putrescible material in the raw sewage.

Where no laboratory is available the operator may get a fairly good idea of the concentration of his sewage by the use of an Imhoff cone. This is a conical glass jar holding 1000 cubic centimeters of sewage to a mark made on the cone. The jar is filled to the mark with sewage and allowed to stand for two hours. Upon standing the settleable solids settle out in the bottom of the cone and the percentage by volume read from graduations in lower part of cone. This is a valuable test but as it is based on volume measurement and particles vary in density, and there is difficulty in getting them to settle compactly, the method is only approximate.

The total suspended matter may be determined, where an analytical balance is available, by filtering a measured volume of sewage through a Gooch crucible. This is a porcelain crucible with perforated bottom. A mat of pure asbestos is formed on bottom of crucible and the whole dried and weighed. By drying and weighing the crucible after filtering the sewage through it, the amount of suspended matter (settleable and colloidal) is indicated by the increase in weight. If suspended solids are determined in this way on a fresh sample of sewage and again on the top liquid after the sewage has settled for three hours, the difference in weighings will represent the settleable solids by weight. These determinations of suspended and settleable solids are most important in sewage treatment and should be made frequently and systematically. Other solids determinations on raw sewage which may be made less frequently, and which are of secondary importance for routine operation, are the total solids, total organic matter and total ash or mineral matter. A measured amount of sewage is evaporated to dryness over boiling water in a weighed dish. After drying, the dish is again weighed and increase in weight represents total solids. By burning this residue to ash and reweighing we have the volatile organic matter represented by loss in weight. The difference between total solids and organic solids will be the ash or mineral solids.

For determining the putrescible matter or material that is going to require oxygen, in its treatment in the plant or in the stream, two determinations are available. The first one has not a great degree of accuracy, but may be used where no laboratory is available. This consists in filling

glass-stoppered bottles with the sample and after the introduction of a small quantity of methylene blue solution, allowing to stand at a temperature as near 20° C. as possible. The material demanding oxygen in the sewage takes it from solution, and when all oxygen is used the methylene blue is decolorized. The putrescibility of the sample is rated inversely by the number of days it requires for decolorization.

The second test which requires considerable laboratory equipment is known as biochemical oxygen demand. The actual content of the dissolved oxygen present is determined in the sample and after holding for a period of time (usually 5 days) at a constant temperature of 20° C., the oxygen is again determined. The difference indicates the amount of oxygen demanded by the sewage under conditions simulating those found in a stream. Where insufficient oxygen is present to satisfy the depletion as is the case with raw sewage, additional oxygen is provided by diluting with water having abundant oxygen and applying a factor representing the number of dilutions of the original sample.

This test probably furnishes more information than any other used for sewage works control. In fact one authority refers to sewage treatment as "a glorified oxygen demand test." It may be used as an index of the strength of raw sewage as well as a measure of the efficiency of the various units.

These determinations, together with the reaction or pH, constitute the routine determinations usually applied to raw sewage and the various effluents. Other determinations may be found necessary at various times and with various sewages. It is well to establish, for a purpose that will be discussed later, the normal content of organic nitrogen in the sewage, though it is not necessary as a routine.

Tank Effluent Samples.—As the function of a settling tank of any kind is to settle out the portion of suspended solids that are settleable, the determination of the content of suspended and settleable solids, as previously described, is of primary importance. Since this material contributes largely to the biochemical oxygen demand, that determination on the tank effluent will indicate tank efficiency.

Methylene blue putrescibility tests or biochemical oxygen demand may be run according to facilities available.

Sludge Digestion Samples.—In the digestion of sludge the volatile organic matter is converted to gases which pass off into the atmosphere. The mineral matter is unchanged. The reduction in percentage of organic matter or, conversely, the increase in percentage of ash, therefore, indicates the degree of sludge digestion. Sludge digestion proceeds best with a reaction about 7.3 pH. Lower pH indicates imperfect process of digestion. The pH should be determined on the sludge as a routine. As the digestion process proceeds slowly it is not necessary to determine ash and organic matter except at infrequent intervals.

A weighed amount of sludge is placed in a weighed dish. Drying of this at a temperature slightly above 100° C. and reweighing will give moisture content, and burning to ash, as in total solids of sewage, will give ash and volatile organic matter. An occasional sample of freshly deposited solids should be run to establish ash content of fresh solids, which varies in different sewages and must be known to judge of ash increase during digestion.

Filter Effluent Samples.—Sewage filters function by coagulating the colloidal solids and depositing the coagulated particles. They also oxidize the putrescible matter to more stable forms. Suspended solids and biochemical oxygen demand are the important control determinations. As the oxidation process consists largely in converting organic nitrogenous material to nitrates, the determination of nitrates in filter effluent is of value. Many operators composite samples from daily composites to weekly samples, preserving with addition of a small amount of sulphuric acid, and determine nitrates weekly on this. To interpret the significance of nitrate content one must know the nitrogen content usually found in the raw sewage. A sewage strong in nitrogenous matter produces more nitrates than one weak in this constituent. Where no laboratory facilities are available, the methylene blue test is applicable to filter effluent.

Secondary Settling Tank Samples.—The effluent from secondary settling tanks should be analyzed for suspended solids and biochemical oxygen demand or methylene blue stability.

Activated Sludge Plants.—For control of activated sludge plants the raw sewage and final effluent alone need be sampled and tested, following procedures outlined for filter effluent. In addition, hourly determinations must be made of volume of solids in aeration tanks, by subsidence in tall graduated jars.

Stream Samples.—As the object of sewage treatment is to relieve the burden upon the stream into which the effluent is discharged it is most important that continuous tests be made and recorded on samples from the stream above and below the outfall. The usual determinations are dissolved oxygen and biochemical oxygen demand. These results are rendered more valuable in conjunction with stream flow records.

Special Laboratory Tests.—In addition to these commonly used routine control tests, special treatment processes require special tests. Where activated sludge is conditioned for filtering special laboratory tests are applied. Where chlorination is practiced residual chlorine and chlorine demand must be determined. If gas from digestion tanks is utilized as fuel the methane content is useful as a control. Complications in plant operation may require special testing. Thus, when odor nuisances develop the hydrogen sulphide content at various points should be determined.

The State Board of Health will soon issue a bulletin on sewage plant operation, in which laboratory tests and necessary equipment will be described in detail. The routine testing for control of such a plant is no more difficult or complicated than the control testing used in water plant work.

Laboratory Control of Sewage Disposal.—The importance of certain tests, which the plant operator may make to determine the efficiency of his plant, is emphasized in a paper by P. J. A. Zeller.

One of the simplest and most valuable tests is the hydrogen-ion concentration. This test is applicable to raw sewage in determining the presence of acid or alkaline trade wastes; to the contents of the sedimentation tank where it indicates too long a retention period by a drop of more than 0.2 pH unit; to a percolating filter where a pH of 0.6 unit must be maintained; and to digestion tanks where digesting solids should be kept at a pH of 7.3 to 7.6.

Numerical data on suspended solids show the amount of solids removed and the gas yield to be expected from digestion, and, in analyses of digested sludge, the extent of digestion which has taken place.

The quantity of hydrogen sulphide may be determined by a simple titration.

Chlorine dosage as applied to effluents may be adjusted by means of the ortho-tolodine test to give disinfection without waste.

Tests for ammonia and nitrates on influents and effluents of filter units determine the extent of oxidation effected, which is an index to the efficiency of the units.

One of the most important tests and one particularly applicable to effluents is the biochemical oxygen demand. It is also valuable because it may be applied at any stage of the sewage disposal process to show what is taking place. A similar but simpler test is the oxygen consumed value. The methylene blue stability test, simplest of all, is useful although highly relative.

Bacteriological tests serve as an index of pollution; to control bacterial counts in effluents; to check efficiency of chlorination; to control chlorine dosage consistent with safety and economy; and to aid in reducing water treatment and in preventing epidemics where a stream is a source of potable water supply.—*Proc. Eleventh Texas Water Works Short School*, pp. 130–133, January, 1929.

Cost Keeping[1]

By A. K. Warren[2]

The cost accounting of a sewage works or sewer system is essentially the same as for any manufacturing plant or other work. Its value lies in its ability to provide a reliable basis for a comparison of unit costs, and as a gauge of the efficiency and relative value of different processes. The proper use of cost figures is quite as important as their proper compilation, and the relationship of costs to results cannot be overlooked.

The ordinary municipal accounting system, while eminently satisfactory for its particular purpose, is not suitable for the accounting of costs of sewage treatment works and it is almost imperative that the two systems be kept separately. Sewage treatment costs should be independent in order to show detailed amounts in connection with the plant and system, but in no way should these details encroach upon, or attempt to modify the accounting system of the municipality.

The prime requisite of a satisfactory cost accounting is the truth of its figures. By this I do not mean the truthfulness of the individuals using the system, but that the figures, themselves, be so set out as to give a complete and definite story. This thought may be made clear by quoting two paragraphs from a letter directed by Mr. Rawn, Assistant Chief Engineer of the Sanitation Districts, to the Chairman of the Committee on Cost Keeping:

"Two features stand out clearly to me as being vital, both to the continued successful operation of a sewage treatment plant and as a guide in future design. First, the cost of operation as related to flow and other conditions at the plant site, and second, the very simplest possible adequate record of the plant chemistry and biology. The two are, to some extent, related and one of course will reflect conditions in the other, and the success or failure in plant operation can only be judged by comparative analysis of both.

"As to cost of operation, this is apparently all too many times misinformation. Sometimes it appears to be deliberate and other times misapprehension of another's statement or effort. In my opinion there is nothing to conceal in the cost of operation, and the only way an intelligent opinion can be formed is by a detailed inspection of the detailed cost. Also an inspection of the results achieved with the type of plant in operation. It also appears to me that plant costs should be set out so that one can judge whether or not there is included in the item of cost all of the features which should be there, that is, field cost, field cost plus field engineering, and field cost plus engineering, central administration overhead, depreciation on the investment and interest charges."

To be of any practical value the cost accounting must include all cost and charges, whether they be direct or indirect, properly segregated to their particular phase of the works.

Differentiation should be made between purely operating costs and

[1] *Presented at Second Annual Meeting, California Sewage Works Association, Oakland, October 8, 1929.*

[2] *Chief Engineer, Los Angeles County Sanitation Districts.*

charges for investigations or experiments, which are really incidental to design and properly a construction cost.

Freeborn (*The Surveyor*, July 12, 1929) points out the desirability of carrying depreciation accounts and making annual depreciation charges for capital expenditures in lieu of loan redemptions and interest charges. Interest charges on one plant may be at a maximum, while on another plant loans may have been retired. In the latter case the interest cost is not actual, but nevertheless the investment remains and for cost-keeping purposes the plant should be charged with the full rate of interest and depreciation.

Each function of the County Sanitation Districts' plant is segregated into units, which are further subdivided as to each piece of equipment or machinery. Distribution is made of the power, labor, material and supplies, repairs, water and transportation to each of the units. Labor is divided into direct charges and proportional charges, that is, work performed specifically on any unit, and the proportional charges of general work done on the plant. The total gives purely operating costs. Overhead and depreciation are added to give total costs, such as operation plus overhead, and operation plus overhead plus depreciation. All of this is summarized to give, at a glance, the total cost for each of the units. Another summary gives a monthly total of the various charges or services, such as power, labor and material. At the end of the year the monthly costs are summarized to give a yearly total. All costs are computed to cost per million gallons. Appropriate distribution sheets are used for the purpose of distributing the expenditures, as they arise, to the proper unit and purpose.

In the case of the Sanitation Districts, expenditures for work accomplished are made from funds raised for the particular purpose of sewage disposal. No work can be performed for the sewage disposal plant by another department without charge, as is the case of municipal works, where the Street Department or Park Department sometimes does certain work for the sewage disposal plant without its cost being charged to the plant. Thus the Sanitation Districts are assured of knowing the total cost without exception.

A standard system should be flexible so that it may be used with equal ease for a large plant using intricate methods, or a small one of quite simple operation. The principle would remain the same, however, and items not applicable need not be considered. The Sanitation Districts' plant and cost system is not so elaborate as the one described by Freeborn, yet the principle is the same. A sample of the unit summary sheet is attached. Details of supplying the necessary information to the cost accountant and for purposes of record can be worked out to suit individual needs.

In working out a standard method of cost accounting, it is hoped that our committee will take into account the advantage of interchange of cost

records of plants in other parts of the country. Instead of the Association adopting a standard form directly, it may be advisable to have the Federation appoint a national committee to develop a standardized code of cost accounting out of material suggestions and records provided by each of the associations. This plan was suggested by Mr. Radebaugh at the Second Annual Meeting of the Central States Association held at Indianapolis on June 21, 1929, in his paper "Standardization of Costs in Sewage Treatment Works," and the following motion by Mr. Hansen was unanimously adopted:

"*Resolved*, that the Executive Committee begin at once to arrange a national committee to follow out the recommendations in Mr. Radebaugh's paper, namely, that this organization recommend to the officials of the Federation of Sewage Works Associations that a national committee be developed to standardize a national code of accounting adaptable to sewage treatment works operation, which will make possible standard construction and operation cost for such projects; and that this committee meet with the view of advising on ways and means of obtaining accurate cost data."

Editor's Note. Mr. Warren's paper includes blank forms used in cost accounting by the Los Angeles County Sanitation Districts. He will supply these forms to those interested in more detailed information than is given in his paper.

LOS ANGELES COUNTY SANITATION DISTRICTS

COST REPORT OF JOINT DISPOSAL PLANT

Account no. Month of 19

Unit

Item

Original cost in place ..... =$

Cost in place to 19 ..... =$

Additional costs for month of ..... =$

Total cost in place to 19 ..... =$

Total depreciation to date ..... =$

Remaining value in plant ..... =$

Estimated life ..... = Years

Monthly depreciation of total cost ..... = %=$

DETAILED COSTS

1—Power:

KWH at c. per KWH ..... =$

2—Operation—Labor:

Direct charges ..... =$

Proportional charges ..... = ... =$

3—Operation—Material and Supplies:

Direct charges ..... =$

Proportional charges ..... = ... =$

4—Repairs and Minor Additions:
Labor ..... =$
Material ..... = ... =$

5—Water:
Proportional part of Unit No. 100 ..... =$

6—Transportation:
Direct charges ..... =$
Proportional charges ..... = ... =$

7—
8—
9—
10—

Sub-total ..... =$
Quantity for unit cost = M. G.
Cost per M. G. ..... $

11—Field office charges ..... =$
12—General office charges ..... =

Sub-total ..... =$
Cost per M. G. ..... = $

13—Depreciation ..... =$

Total cost ..... =
Cost per M. G. ..... $

The Costing of Sewage Disposal Works.—In a paper presented before the Association of Managers of Sewage Disposal Works at York, England, Mr. Walter F. Freeborn discussed the value and necessity of cost accounting systems. Systematic records should be kept of all expenses as they occur and should be summarized so that all labor, materials and services will be charged to the process for which they are used. Costs should be divided so that comparison can be made between different processes serving a common purpose, same process operated at different works, work of individual machines and appliances, and the work performed by direct labor and contract. The system should be applicable to any new process which may arise. All jobs should be given numbers so that labor, materials, tradesmen services and power costs can be charged to these jobs. Various record forms are shown. A diagram is shown to illustrate the relationships of the various forms.—*The Surveyor*, **76,** 29–35, July 12, 1929.

Suggestions for Financing Sewage Treatment[1]

BY HOWARD R. GREEN[2]

Sewage disposal is becoming of greater interest to the larger cities and towns of Iowa each year. With this increased interest there arises a natural desire to investigate the financing possibilities. Up to the present time, the greatest activity in sewage treatment matters has been confined to the smaller communities. The larger towns and cities felt the need of sanitary sewers at an earlier date than their smaller neighbors. They therefore constructed their main and lateral systems years ago and discharged the flow into adjacent streams, there being no State Board of Health to interfere. The smaller communities, on the other hand, delayed the construction of sewers until a later date. In the meantime, the State Board of Health had been organized with authority to pass upon plans of all cities and towns in the State in sanitary matters. The approval of the State Board, in most cases, has been dependent upon the inclusion of sewage treatment works. The result is that we have at present, a peculiar condition in Iowa: the smaller communities, which are the least offenders against sanitary regulations and the least able to finance sewage treatment works, have in the main, constructed and paid for such improvements, while their larger and wealthier neighbors, the greatest offenders in the matter of stream polution, are only beginning to consider the problem, if indeed they have gone that far.

The maintenance of sewage treatment works in the smaller communities is a matter of minor importance so far as expense is concerned. It is only in the construction of works adequate for the larger communities that the matter of financing plant operation becomes worthy of serious consideration. There are then, two problems to be considered: first, that of legally making an equitable distribution of the first cost of construction, and second, a similar distribution of maintenance costs. Before entering into a discussion of the possible methods of financing, an outline will be given of the existing statutes governing the construction and operation of such works in Iowa.

Legal Aspects.—Any Iowa city or town may legally construct sewage treatment plants. Such plants, in the eyes of the law, are considered as a part of the sewerage system. They are financed in the same manner as that provided for sewer systems. They may be constructed as a part of and in the same contract with the sewer system, or they may be built later as an addition thereto. Municipalities have the right to establish sewer districts by ordinance. A city may be divided into several such

[1] *Presented at the Eleventh Iowa Sewage Treatment Conference, Iowa State College, Ames, Oct. 22, 23 and 24, 1929.*

[2] *Pres., H. R. Green Co., Consulting Engineers, Cedar Rapids, Iowa.*

districts, or the entire incorporated area may be included in one district. All the territory in a sewer district may be assessed for the cost of constructing sewage treatment works.

Special Assessment.—This tax may take the form of a special assessment levied against the various lots, parts of lots or parcels of ground within the district. All such lots must be drained or be susceptible to drainage to the site of the future disposal plant. Such assessments must be in proportion to the benefits to each property and must not in any case, exceed one-fourth of the fair value of the property in question. Such special assessments are payable in the same manner as other municipal improvement costs, that is, in ten annual equal installments paid at the same time and place as the March first installment of the ordinary taxes. Any property owner may pay off the unpaid portion of such tax at any time. Interest on the deferred payments must not exceed six per cent. The city may authorize and issue special assessment certificates against each lot in amount equal to the total of the assessment against that lot. The interest on such certificates shall not exceed six per cent.

The city also has the right to consolidate the special assessments and issue special assessment bonds in amounts which are multiples of $100, but not exceeding $1000. These bonds mature serially in amounts equal to the anticipated collection of special assessments each year throughout the ten-year period. They are, however, callable on or before the date of maturity. The interest on such bonds must not exceed five per cent per annum.

These bonds are not general obligations of the city as a whole so far as running against the statutory limit of indebtedness is concerned. In other words, they are not considered a city debt, but are an obligation of the privately owned property assessed, the city merely acting as collector for the bond holder. A recent Supreme Court decision, however, makes these bonds an actual debt of the city so far as payment is concerned, on the theory that the city in issuing the bonds represents that it has done everything necessary to make the securities good, and failing to do so, must assume the obligation of payment.

If the total of all special assessments levied falls short of the actual cost of construction of the treatment works, the city as a whole must pay the difference. This difference may be paid from any available balance in the general fund, the sewer or sewer district fund, the sewer outlet, purifying plant and dump ground fund. If the available balance in these three funds is insufficient to meet the deficit, a five mill annual levy against either of the sewer funds may be anticipated over a period of years not exceeding twenty. In anticipation of the collection of these millage levies, bonds against the respective funds may be issued at not over five

per cent per annum, both interest and principal to be paid from the respective funds.

The city may dispose of these bonds at public sale at a price not less than par, and use the funds from such sale to pay the cost of construction of the treatment works. The total of general obligation bonds so issued shall not exceed, when added to all other general obligation bonds outstanding, the legal limit of indebtedness, which is five per cent of the actual value of taxable property within the city.

It will thus be seen that the right to build treatment works and the machinery for financing the construction of the same has been amply provided. So far as financing the original construction is concerned, three paths are open to the city administration: first, the entire cost may be assessed against benefited property as a special assessment and the assessments collected within ten years; second, the entire cost may be paid from one or more of the sewer funds; third, a combination of these two methods may be used.

Millage Tax.—The following schedule is typical of the usual application of these laws. A sewer district is created by ordinance. This district usually embraces the entire town. Contracts are awarded for construction following the approval of plans by the State Board of Health. When the construction is completed and payment is due, each lot is assessed for its share of the full cost of building the sewer system proper. In addition to the straight sewer assessment, each lot is assessed for its share of approximately one-half of the costs of the disposal works. The other half of the plant cost is financed by levying a special millage tax against all the real and personal property within the sewer district, and bonds are issued in anticipation of the collection of both the special assessments and sewer fund taxes. The bonds are sold and the proceeds used to satisfy the costs of construction.

Theoretically this system provides all the machinery necessary to finance the first cost of construction. The maintenance costs must be financed from available moneys in the general or sewer funds from year to year. These funds are replenished annually by millage taxes against all the property in the town. The system of financing as outlined has two great advantages: first, it furnishes a sure and positive means of paying the cost of construction and operation, and second, it is entirely legal.

The difficulty with the system, especially in larger communities, is to so levy the assessments and taxes that the cost to each individual property will represent its fair and equitable portion of the expense.

Tax Allocation.—The basic principle underlying all tax matters is that the taxes shall be in proportion to the benefits derived, always taking into consideration the ability to pay. The first difficulty encountered in levying a special assessment against property benefited by the construction

of sewage treatment works, is to determine how that cost shall be divided. Shall a residence property pay at the same rate per front foot or per square foot as a commercial property? Shall a flat building housing fifty people on a sixty foot lot, contribute the same amount toward construction and operation, as a family of three living on an adjacent sixty foot lot? Shall an industry occupying ten acres of space pay at the same rate as a similar sized truck garden in the borders of the city? Obviously the answer to all these questions is negative, yet in the great majority of cases, a flat area is determined and the assessment spread on that basis.

Let it be assumed that an honest attempt is made to so levy the special assessments that the nature of business conducted on any particular property or the occupancy of any lot be taken into consideration in fixing the amount of the assessment. Let it be assumed that the result of such a carefully prepared schedule truly represents an equitable division of the costs on the basis of the service demanded by and rendered to each lot. Even then the problem is not solved, because during the period of years through which the plant operates the occupancies and natures of businesses conducted upon these lots change. Obviously no rigid system can be devised which will be equitable in its division of the costs except at the moment the assessment is made.

The foregoing criticism is based upon the plan of financing entirely by special assessments. If the city elects to finance by millage levy tax, another type of objection is introduced. Under the millage levy tax system, the money collected from any property depends entirely upon the valuation of that property. It is therefore apparent that a $20,000.00 property contributes twice as much toward the construction and maintenance as a $10,000.00 property. It is also true that all properties of equal valuation contribute at the same rate regardless of the type of occupancy of the property.

Difficulties in Tax Apportionment.—An analysis of the problem thus far discloses this fact: It is almost impossible to make an equitable division of the cost on the special assessment basis. Even if a fair division of cost is determined, changing conditions make the system inequitable almost immediately. To finance by millage levy recognizes only the valuation of the properties and is in no way dependent upon the sanitary service demanded by and furnished to the properties. A combination of the two methods, as usually used, is almost as faulty as the use of either one separately.

Proposed Improvements.—Having set out the existing rules of procedure and commented critically upon the results obtained by their use, it is next necessary to suggest some betterment of the system. The cost of a sewage treatment plant as well as the cost of its maintenance and operation, should be paid by the various properties within a city in pro-

portion to the use and benefits made by, and accruing to each property. The cost of a sewage treatment plant is dependent upon its size. Its size is determined by the total quantity of sewage which must be treated. This total quantity of sewage is made up of a hundred, a thousand or twenty thousand contributions from as many properties. The cost of treating the sewage from any property is not dependent upon the valuation of that property, nor the size of the property, but upon the quantity of sewage produced by that property. A $20,000.00 creamery or laundry may produce more sewage and require more treatment expense than a million dollar warehouse. A property pays for electric energy on the basis of current consumed plus a standby or minimum charge. It pays for gas, water and other utility products on the same basis. The size of the property is no gauge of the service rendered, nor is the value of the property a consideration. With these well established principles in mind, a solution of the problem is suggested.

First, there is a general benefit to a community, and to every person and property within that community, by reason of improved sanitary conditions, whether or not each person or property is directly served. This indirect benefit is believed to be only a small percentage of the direct benefit to properties actually served by the system. The plant must be designed to take care of outlying properties not yet connected with the system. These properties should bear some small portion of the expense of construction and operation until such time as they actually connect with the system and contribute at a higher rate for direct benefit. Let it be considered that ten per cent of the cost of construction and maintenance should be borne by the city as a whole as a general benefit tax, the cost to be financed by millage levy under one of the sewer funds. There remains ninety per cent of the cost to be accounted for.

Sewer Fees Based on Volume.—Inasmuch as sewage is usually defined as the used water supply of a city, it appears that the consumption of water by any property is a very accurate index of the demands made upon a sewage treatment plant by that property, and the benefits from such an installation accruing to that property. It is therefore apparent that if the quantity of water consumed by a property is used as a gauge and a charge is made for sewage treatment on the basis of that index, the result would be a fee in proportion to the benefits derived.

When the sewage treatment plant has been completed and its final cost determined, if that cost is spread over a predetermined number of years for financing purposes, and the necessary interest charges are added to the proposed serial retirement, this total when added to the estimated maintenance costs of the works will result in a figure which should represent the yearly total of collections necessary from the several properties within the city. If this total be balanced against the total annual water rentals,

a percentage will be determined. This percentage will be equal to the increase in water rates necessary to provide funds when collected in the same manner and at the same time as water rentals, and should be kept in a separate fund and transferred by the water department to the sewer department.

In most cases, a sliding scale of water rental rates is in force and it is believed that this same sliding scale would be equitable in the case of sewage treatment. The collection of the fees and accounting would require no additional clerical help.

There are, in every city, a number of properties which have developed private water supplies. These cases would of necessity, be covered by ordinance requiring the metering of such supplies and the payment to the city sewer fund of an amount equal to the sewer fee paid by other similar consumers of water. In the case of water consumers not contributing to the sewage flow in proportion to the water consumed, rebates authorized by ordinance might be arranged.

Advantages of Sewer Fees.—The advantages claimed for such a system are as follows: It would insure a far more equitable distribution of sewage treatment costs than is now the case. It would eliminate more or less arbitrary decisions as to the rate of payment by various classes of property. It would be absolutely flexible. A change of occupancy with consequent increase or decrease in the amount of water consumed and sewage produced would immediately be reflected in the rate paid by that property. It would relieve city councils and their authorized employees from long and more or less fruitless discussions as to the proper division of cost of construction and operation. It should eliminate the large majority of objections to assessment methods encountered when each new disposal plant is constructed.

It would follow in effect and in theory, the principles already in operation for the financing of State Highways, whereby the automobile owner contributes towards the construction of highways in proportion to the fuel consumed, which is an index of the use to which he puts the highways.

In conclusion, it is hoped that this discussion has called attention to one possible method of eliminating what is probably the most inequitable tax situation in effect at this time. There are, of course, many details to be worked out, but it is believed that a fairly simple amendment to the present improvement law would authorize all the altered action necessary.

Sioux Falls Sewage Treatment Works[1]

By R. E. Bragstad[2]

The City of Sioux Falls, with a population of approximately 35,000 people, is situated on a bend of the Sioux River, which is a non-navigable stream. The flow of this river is quite variable, ranging from a minimum recorded flow of 9 to a maximum of 500 cu. ft. per second. As originally designed and built the sewerage system emptied into the river at three main outlets.

In 1910 the city had a population of approximately 14,000 people, and during the next decade its population practically doubled. During this period of growth there was added to the industries of the city a large meat packing plant, which has been steadily growing and has exercised a marked influence upon the liquid wastes of the city up until the present time, when the waste from this source alone is approximately 45 per cent in volume of the total amount of waste produced by the rest of the city.

For several years the volume of flow in the river had been insufficient to provide adequate dilution for the ever-increasing amount of liquid wastes discharged into it. As a result, the river was offensive both to sight and smell for miles below the city, with an absence of fish life, causing much just complaint from the riparian owners down stream. This was the condition which the city faced in the summer of 1925, when the first definite steps were taken to deal with this problem.

In August, 1927, the first units of a sewage treatment works were placed in operation. This plant is what is known as the separate sludge digestion type, with trickling filters, and consists of the following units: Coarse bar screen, 3 grit chambers, measuring weir and flow gauge, 2 clarifiers or sedimentation tanks, 3 sludge digestion tanks, 2 sludge pumps, dosing tank, filter bed and sludge drying bed. To this was added in 1929, a gas collection and heating system for controlling temperatures of the sludge digestion tanks. On account of topographical conditions, the plant is of the gravity type throughout, in so far as the bulk of the city sewage is concerned, the only pumping required being the pumping of sludge. However, the sewage from the packing industry and adjacent district is pumped into the main treatment works from a small sewage pump station.

The city sewage is typically domestic with a small amount of industrial waste, containing about 300 p. p. m. suspended solids, with an average flow at the present time of 2.4 million gallons per day. The industrial waste from the packing plant contains about 1250 p. p. m. suspended solids and the average flow at the present time is 1.9 million gallons per

[1] *Presented at the Meeting of the Missouri Valley Section, American Water Works Association, Sioux Falls, So. Dakota, Nov. 6–8, 1929.*

[2] *City Engineer, Sioux Falls, So. Dakota.*

day. A pre-treatment works at the packing plant consists of a Dorr screen and a Dorr clarifier. By agreement with the city the sewage is delivered to the city plant after being screened and settled.

At the head works are provided two over-flow gates to by-pass the excess flow directly into the river during storms, since a considerable portion of the sewers of the city are of the combined type. Grit chambers consist of three units, each having a capacity of 6,000,000 gallons per day.

The two clarifiers are equipped with Dorr mechanisms to facilitate the removal of sludge. Each tank is 70 ft. square with a depth of 10 ft. 3 in. at the outer wall. They are designed for a capacity of 8,000,000 gallons per day of combined wastes with a $2^1/_2$-hour retention period. On the basis of the present flow of 4.3 million gallons per day the retention period is approximately 4.2 hours. Tests for the removal of settleable solids have shown a removal as high as 97 per cent on a 2-hour basis and a reduction in the biochemical oxygen from 1040 to 480 p. p. m., equivalent to 54 per cent.

Two 4-inch diaphragm sludge pumps of the Dorr type are installed for pumping sludge from clarifiers to digestion tanks and may also be used for emptying tanks and circulating sludge. A 250-gallon-per-minute centrifugal pump has lately been installed as an auxiliary unit for emergency use and is used also for flushing scum from the gas domes.

The filter beds cover an area of 4.1 acres, with a depth of 9 ft., and are provided with Rawn tile underdrains. Native quartzite, which is unsurpassed as a filter medium, is used for these beds. They are designed to give a satisfactory effluent with a flow of 8,000,000 gallons per day.

The three digestion tanks are each 85 ft. in diameter and 25 ft. in depth and are equipped with Dorr mechanisms for stirring and scum breaking. Each tank has an effective sludge capacity of 132,000 cu. ft., which, on the basis of present contributing population, gives a sludge storage capacity of 8.8 cubic feet per capita, or figured on the basis of equivalent industrial waste population the storage is 2.8 cu. ft. per capita. Tanks are of the covered type with gas collection domes. Sludge is pumped to all tanks three times daily for a total of approximately $4^1/_2$ hours, depending on the amount of sludge accumulation in the clarifiers. The tanks are rotated in the pumping process to insure equal distribution of sludge.

Underdrained sand beds 1.1 acres in area are provided for the drying of sludge. An over-head carrier system is provided for the removal of dried sludge. Up to the present time, the dried sludge has been used for fertilizing purposes, there being a growing demand locally for the sludge for this purpose.

Plant operation was started August 23, 1927. At this time the plant was receiving all of the sludge from the packing industry, pre-treatment consisting only of fine screening and grease skimming, consequently during

the ensuing winter a heavy load of raw sludge, at low temperatures, was accumulated with very little gas production.

Routine laboratory tests were made to determine the pH value of the sludge in the digestion tanks and lime was added regularly in order to bring the reaction from the acid to the alkaline side. This was continued throughout the year.

Early in May, 1928, when air temperatures were steadily increasing, No. 1 tank showed evidences of foaming. This was soon followed by a similar occurrence in tanks No. 2 and No. 3, with the result that the foaming condition increased in all tanks and continued throughout the summer. In order to keep the foam within bounds, it was necessary

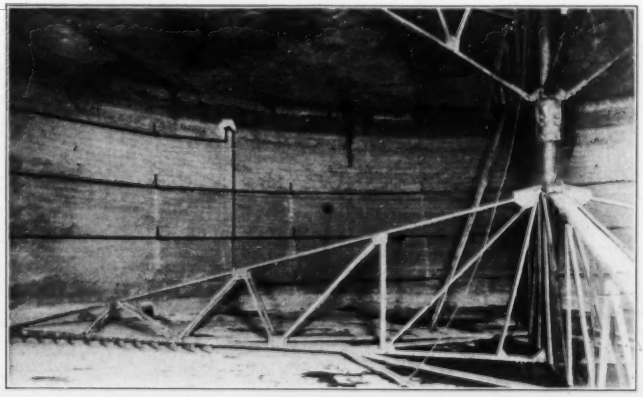


FIG. 1.—Heating Coils in Sludge Digestion Tank, Sewage Treatment Works, Sioux Falls, South Dakota.

to draw sludge frequently from all tanks. The addition of lime and the hosing of the scum surface failed to improve this condition and at times seemed to aggravate it. Foaming continued during all of the summer and into the fall with no marked improvement. An analysis of the sludge indicated that no ripe sludge had developed, the volatile matter running between 60 and 70 per cent and the ash approximately 35 per cent, thus it was evident that the tanks had failed to establish alkaline digestion. The temperature of the sludge in the tanks during the winter reached a minimum of 48° F. at the bottom, this being approximately ground temperature. In July the maximum temperature recorded in the tanks was 68° F. on top and 62° F. at the bottom. In September these tempera-

tures again began to drop with the cooler weather with no prospect of improvement in the foaming and scum conditions. Scum, by this time, had accumulated on the top of all tanks to a depth of 3 or 4 feet. Low temperature, the size of tanks, character of sludge and lack of temperature control seem to be factors that precluded the establishment of alkaline digestion.

It is well recognized that temperature is one of the major factors in the digestion process, and experience here and elsewhere has demonstrated that uncontrolled tanks are prone to cause seasonal difficulties in the way of foaming and scum formation. This will be only too well recognized by many plant operators, who have spent many long weary hours combating that most persistent operating enemy—foam and scum.

It was with the intention of providing, if possible, this temperature control, that a gas collection and sludge heating system was planned and

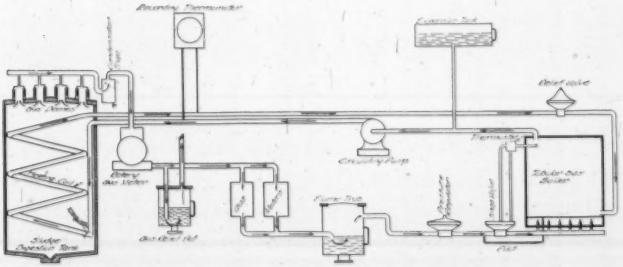


FIG. 2.—Diagram of Gas Collection and Sludge Heating Apparatus, Sewage Treatment Works, Sioux Falls, So. Dakota.

installed in the winter and early spring of 1929 by the City Engineering Department. This equipment consists of hot water coils in the digestors, gas collection domes, Bryant gas boiler with thermostatic control, circulating pump, recording thermometer, Connersville rotary gas meter and 2 No. 60-A displacement gas meters for measuring the gas burned. Gas is collected under the domes and brought to the boiler house through a 4-inch gas main. The excess gas which is not required in the boiler is, at present, allowed to escape through a water seal relief valve. A flame trap is provided which prevents the possibility of a flashback from boiler to meters.

The heating system was first placed in operation on March 30, 1929, taking gas from No. 3 digestor, which was then the only one in operation, and receiving all of the sludge. At the beginning the meter registered a flow of gas of about 800 cu. ft. per hour, and with a gradual rise in tem-

perature the gas production increased until the maximum of 3300 cu. ft. per hour was recorded. Doubtless this is greater than the average gas production, and was due in part to the digestion of accumulated undigested sludge. The present gas production is about 2500 cu. ft. per hour. Sixty days thereafter, tanks Nos. 1 and 2 were placed in operation and the temperatures of all three were gradually raised until a temperature of 85° to 95° F. was reached.

Alkaline digestion was established and maintained in all tanks from the time temperature control became effective. The pH determinations have shown consistently 7.2 to 7.4 without the addition of any lime. There is apparently rapid digestion with a clearly defined line between the sludge and the supernatant liquid. A recent analysis of sludge shows 12.5 to 13.87 per cent total solids and 66 per cent ash, indicating a well-digested sludge. Sludge dries well on the sludge beds and is being used, for the most part, as a fertilizer. Analyses of the gas show a heat content of 709 B. T. U. per cu. ft. with approximately 65 per cent methane and 35 per cent carbon dioxide.

Since March 30, 1929, there has been generated approximately 12,500,000 cu. ft. of gas. Of this amount 5,500,000 cu. ft. have been utilized for heating. This represents about 44 per cent of the amount generated. The balance, or 56 per cent, has been wasted. Another winter's operation will reveal just how much excess gas is available for other uses. Recently a gas burner has been installed in the boiler of the office and laboratory building and gas is being utilized for heating. Steps have also been taken to install a small gas burning incinerator for burning the rakings from the bar screen.

Up to the present time the results obtained through the installation of this heating equipment have been very satisfactory. It has, in effect, increased the capacity of the digestion tanks and doubtless delayed, for some time, the date when additions will have to be made to take care of an increasing amount of sludge. It has effected a marked decrease in odors prevalent about the plant during the first year of operation and eliminated the fuel cost for heating the office and laboratory building. Whatever excess gas still remains is doubtless of potential value. This heating equipment was installed by the City Engineering Department at a cost of $10,500, including the remodeling of the building. It is probably one of the largest, if not the largest heating installation of this type in operation in this country at the present time.

Plant Costs

Main treatment works	$630,000.00
Sewers and appurtenances	95,000.00
Gas collection and heating equipment	10,500.00
Total cost	$735,500.00

Designing Engineer, A. A. Chenoweth
Consultants, Pearse, Greeley and Hansen
City Engineer, R. E. Bragstad

The operation of the plant is under the supervision of the City Engineering Department.

The Sewerage Works of Tokio.—In view of the recent World Engineering Congress held in Japan, interest has been centered on Japan's sanitary problems. Mr. Zenro Hara, Chief Engineer of the Department of Public Works of Tokio, has printed a pamphlet (November, 1929) on the sewerage and sewage disposal works of this city.

In 1876, the necessity of sewerage systems was recognized, but it was 1911 before any action was taken to construct sewers. The combined sewerage system is used. The city is divided into three main drainage districts.

The Mikawashima plant in District 2 was placed in operation in 1921. It covers an area of about 46 acres and is designed to care for a population of 600,000. This plant consists of two sets of detritus tanks and screens, five sedimentation tanks, twenty-eight trickling filters covering a total area of about 7 acres, two humus tanks and two sludge tanks. The effluent is discharged into the Sumida River.

Experimental work on the activated sludge process is under way at this plant, which treats 830,000–1,150,000 gallons of sewage per day, mechanical agitation of the Sheffield type being employed. Thirty-seven thousand gallons of sewage per day are treated by the activated sludge process using air alone. A comparison of trickling filters, activated sludge process with mechanical agitation, and activated sludge process with air alone showed the following results based on analyses of the effluents from January to November, 1929: suspended matter, 84, 68 and 62 p. p. m., respectively; oxygen absorbed in 4 hours 7.35, 5.34 and 5.03 p. p. m.; albuminoid ammonia as nitrogen, 1.10, 1.13 and 0.88 p. p. m.; *B. coli* 1700, 1300 and 1100 per cc.

Another plant is under construction, the Sunamachi works, District 3, designed to treat wastes for a population of 670,000. The plant will consist of four sedimentation tanks and two reservoirs for storage during flood tide. The settled sewage will be discharged into the sea.

The design of a plant for District 1, the Haneda Disposal Works, has been proposed to deal with a population of 2,170,000. This plant will comprise four sets of detritus tanks and screens, eleven sedimentation tanks, and a disinfection chamber. The settled and disinfected sewage will be discharged off the coast of Haneda.

The Problem of Interception and Treatment of Sewage at Buffalo, New York[1]

BY C. L. HOWELL[2]

A paper which describes the collection and treatment of sewage at Buffalo is concerned with something that does not yet exist. Buffalo, which is among the dozen most populous cities in the country, still discharges untreated sewage into surface waters. At the present time, however, this city is initiating a large scale program, which has for one of its objectives the collection and treatment of city sewage. This paper is a brief outline of the program which is contemplated, and it indicates some of the points which have arisen during the technical studies which are now in progress.

Description

The foundation of the present Buffalo sewerage system found serious beginning in the years which followed the construction of the Erie Canal, which connects with Lake Erie and Niagara River at Buffalo. Accordingly, it was but natural that the canal should have been used as the initial outlet for much of the city's waste. In time, this practice led to nuisance and, in 1883, there was built an intercepting sewer which paralleled the lake front in such a manner as to intercept the sewage from the several trunk sewers. The sewage was thus collected from what might be termed the central city and was carried to discharge into Niagara River at a downstream point. This interceptor, together with two later trunk sewers, constitutes the skeleton of the present city sewerage system.

Parenthetically, it is interesting to note that this intercepting sewer project, as a move of major sanitation, represented the advice of such pioneers in the field as John W. Adams, Moses Lane, William Sooey Smith, E. S. Chesbrough, J. Herbert Shedd and George E. Waring, Jr. The last of these prepared the detailed plans for the undertaking, and from all standpoints they are thoroughly interesting.

Buffalo today has a population estimated at about 580,000 people. Its sewerage is on the combined plan with major outlets into Niagara River. In addition to these main trunk sewers, however, there are a number of smaller sewers, which serve low-lying and flat territory within the drainage area of Buffalo River. Buffalo River is also the center for many of the industries of the city, and it receives many direct contributions of industrial wastes. This stream, which is in effect a slack water extension of Lake Erie, is quite offensive in appearance and constitutes a local nuisance of certain degree.

[1] *Presented at the Fall Meeting of the New York State Sewage Works Association, Schenectady, N. Y., October 19, 1929.*

[2] *Assistant City Engineer, Buffalo, New York.*

The city area of Buffalo is still practically as it was chartered in 1854. Bounding territory to the north, east and south is, nevertheless, fairly well developed and there have been created within it certain villages, or township sewer districts, which are provided with local sewage treatment works. Some of these discharge effluents into streams which traverse the major city.

Niagara River, which finally receives the sewage of Buffalo, is international boundary water. A treaty between the two countries recites that neither shall use these waters to the detriment of the other. Furthermore, Niagara River is the source of water for several frontier cities and it is also linked to important recreational development in this area.

The General Problem

This preliminary description may serve to indicate, in part, the situation at Buffalo. The problem is that of pollution of water supplies, of violation of treaty rights and of the existence of local nuisance. Buffalo's own water supply is not directly concerned under ordinary circumstances.

In addition to what might be termed health aspects of the problem is the consideration of internal storm water drainage. Drainage in Buffalo has not kept pace with growth, and it is probable that one-seventh or one-sixth of the whole city area is subjected to flooding of greater or lesser frequency and effect.

Remedies, as they may be devised, must therefore be directed to these several objectives, thus:

(*a*) City sewage must be concentrated at one or more points and there treated to a degree that will satisfy treaty obligations and protect water supplies. Additional to these ends, and to a particular extent, it is necessary to eliminate local nuisances which have almost become vested.

(*b*) Particular solution of the health problem must also be framed to accord with the need for major storm water relief drainage.

It is not yet too early to sum the total of the improvements which will be called for under such a program. However, it is probable that the intercepting sewers, sewage treatment works and storm drain outlets will aggregate, perhaps, 20 or 25 million dollars. To this amount it will be necessary to add other and substantial sums in order to provide adequately for internal drainage. A program of this scope is, of course, a serious undertaking for any city, but it must be viewed as the present expression of future needs and as enlarged by the deficiencies of the past. Also, it is probable that any undertaking of this kind will be spread over an appreciable period of time.

Engineering Procedure

In order to evaluate the needs and to outline a particular and suitable program, the city has expanded its engineering force. Also, to act in con-

junction with the local engineers, the city has retained Mr. George B. Gascoigne of Cleveland, Ohio, as a consultant. Mr. Gascoigne, in addition to his personal services, is represented by one or more members of his staff who are in continuous touch with the local work.

Investigations appropriate to the Buffalo sewerage problem have followed a logical development. Studies have been made of the conditions to be remedied or the phases of contamination, of nuisance and of storm drainage to the end of giving particular expression to these several effects of local sewerage. Basic design factors have been determined in accord with the local requirements. In this category are such elements as the area and population to be served, the quantity and quality of sewage, the factors of rainfall and runoff, and the degree of sewage treatment needed to accomplish suitable remedy of those conditions which exist and those which will develop during periods of the future. From basic data thus set up, alternative projects for the collection and treatment of sewage have been outlined and have been contrasted from the standpoint of cost, of accord with requirements, and of harmony with a logical program of expansion. A study of this character is normal to problems of this kind, and it does not call for elaborate description.

Particular Engineering Problems

Of possible general interest in the Buffalo situation are certain problems which have arisen during the course of investigations. Brief comment will be offered on certain of these.

Population and Area.—It is essential to the development of sewage treatment works to have some reasonable idea of the population it will be necessary to serve at different periods. The usual mode of estimating these populations is that of projecting past growth in a manner to accord with the experience of other selected and larger cities. Treatment of this kind assumes normal growth or growth analogous to experience elsewhere. Particularly does it assume territorial expansion. In the case of Buffalo, we have a city which has not enlarged its boundaries for 75 years. Indeed, the situation, as it now exists, renders it a quite serious question whether there is any practicable opportunity for expansion of the city limits. These questions have led to a study of population densities as applied to large areas, with the conclusion that the present city area is approaching saturation. Complete saturation has been set at 26 persons per acre of gross area. With normal increase, this point should be reached in 15 years. However, it should not be assumed that designs are being restricted to this figure. Certain allowances have been made to permit of extensions of sewerage service.

Bearing upon and complicating the situation is the presence of four local sewage treatment works situated within, perhaps, one-half mile of and

along the easterly city line of the major city. These works serve an area which under normal conditions would be within the trend of city growth. The particular question calls for determining whether present development of the area should be regarded as essentially temporary, and as to whether the major city will eventually be called upon to provide sewerage service to such areas, either through annexations or contractual arrangements.

Quantity of Sewage.—In common with many lake cities, Buffalo is a liberal user of water. In 1905 the total pumpage at the city water works was at the rate of nearly 400 gallons per capita daily. Today the consumption is at the rate of 209 gallons per capita daily. This marked reduction is the result of a continued program of waste surveys and of extension of metering. Of the total water consumption about 6 per cent is taken by the railroads. An additional 38 per cent is divided between large industries and commercial users. Strictly domestic use of water is approximately 70 gallons per capita daily, which amounts to about one-third of the total pumpage. It may be of interest to note that while industrial and commercial use of water may run from 12,000 or 13,000 to 30,000 gallons per acre daily, there is decided risk in the universal application of such average units. For example, certain subdivisions of area have been found to yield probable discharge of sewage up to rates of 300,000 gallons daily per acre of area. Laundries and large hotels, together with dairies, are found to be among the largest consistent users of water.

In Buffalo, there has been an attempt to gage some of the sewers. The results do not lead to establishing any strictly universal units of flow. In fact, they very clearly show the difficulties in applying any such general units. The makeup of the area and its topography are found to have a marked influence, particularly upon the industrial and infiltration units of flow. This fact may be unimportant from the standpoint of a sewage treatment plant, but it does have distinct bearing in the design of intercepting sewers. There is also indication that, in some cases at least, it is necessary to make allowances for surface runoff from former streams which have been enclosed. In Buffalo, the sewage flow seems to range between 125 and 600 gallons per capita daily. These units, of course, apply to combined sewers and represent dry weather flow. The average sewage flow for the whole city is apparently quite close to the average water consumption.

Storm Runoff.—Under ordinary circumstances, where the development of sewerage has been along the lines of separate sewers, the question of storm water does not enter, but in the case of Buffalo with its combined sewers this has been the subject of considerable study.

Although precise information is largely lacking, it is generally understood that the first flush of storm flow from combined sewers is quite as highly polluted as is the strictly dry weather flow. From theoretical considera-

tions it would be desirable to establish the peak of this pollution effect to the end of determining a proper ratio of interception. To express this more clearly, intercepting sewers must, of course, be designed to accommodate the ordinary dry weather sewage flow in both average and maximum quantities. If, as in the present case, it is necessary to intercept this flow from combined sewers and, if further, during periods of storm these combined sewers discharged mingled storm water and sewage of certain pollution effects, it is desirable to enlarge the capacity of the intercepting sewer sufficiently to take off certain additional contributions of storm water. The problem is to determine just where to stop. With adequate information, in terms of some pollution yard stick, it might be possible to establish a pollution curve and to design the intercepting sewer to accord with the peak of that curve expressed in gallons per capita daily, or in any other quantitative manner. Efforts in this direction are highly desirable and could well be directed to evaluating the pollution effects of storm flows in various quantities and under variable conditions of area, time and season.

This question of interception may also be attacked from the standpoint of economics. In this direction a detailed analysis has been made of local precipitation as observed from automatic records over a 20-year period. In this study it was necessary to consider the usual record of inches per hour as equivalent to intensities of like amount and duration. From the standpoint that interception was to be applied to major sewer districts with fairly long concentration periods, study of the rainfall was applied to storms of one and two, and of two or more hours duration. For each of these duration periods the storms of record were classified according to the rate of rainfall. The resulting data were used to establish curves of frequencies in terms of rate and of duration.

For any given sewer district with its appropriate critical concentration period, it is thus possible to determine the reduction of storm overflow, which results from the absorption of any given rate of rainfall. This reduction in turn can be studied with relation to the interceptor size and its cost. It is probable that, in many cases, it will be found that a maximum return will be obtained by intercepting the storm water runoff from a rainfall of approximately 0.05 inch per hour. Such a rainfall rate at Buffalo includes some 70 per cent of the total hours of rainfall in the year. Incidentally, the average of the 20-year record shows that it rains some 6 per cent of the total time.

Collecting the Sewage.—The engineering factors in the design of intercepting or collecting sewers at Buffalo are as follows:

(*a*) The trunk sewers are combined sewers from which a measurable amount of storm water must be taken off and controlled.

(*b*) Practically all of the sewers now discharge below water level, and

interception must be devised so as to pick off dry weather flow without running the risk of obtaining back water from lake or river.

(*c*) Both interception and the discharge from sewage treatment works must be planned with a knowledge of the fact that lake and river are subject to a nine-foot variation in extreme levels, with a five- or six-foot variation during a considerable portion of the time.

These several factors in the case of Buffalo are such as to involve pumping problems both as applied to dry weather flow and to such portions of the storm flow as it is desired to treat. These, and other similar matters, are problems which are coming up during the course of the investigations at Buffalo. They are not essentially different from the problems which arise elsewhere, although each case, of course, presents local variations.

After all, the principal fact is that the City of Buffalo has embarked on a program of major sanitation. Preliminary plans have been prepared for sewers and sewage treatment works to serve South Buffalo, which includes about one-third of the population, together with many of the industries. This project has been submitted to the Council and that body has directed the preparation of detailed plans. The improvement which is contemplated includes collecting sewers, storm relief outlets, pumping station, force main and sewage treatment works of the activated sludge type. The estimated cost for these items is $9,400,000. Supplementary to this, the engineers are now completing studies which will lead to a program of sewerage improvement for the balance of the city.

This subject should not be left without recording the fact that the disposition in Buffalo is not to lag in this matter. There is general appreciation of the obligations of the city and a general willingness to meet those obligations and even to go beyond them.

The Relation of the Designing Engineer to the Sewage Treatment Plant Operator[1]

BY H. BURDETT CLEVELAND[2]

The relation of the designing engineer to the sewage-works operator is of very definite importance when it is considered that the only justification for the expenditure of public funds in building sewage treatment plants is to bring about proper treatment of sewage before its discharge into watercourses.

Such treatment may be partial or more or less complete, depending on the available dilution in the stream or body of water into which the plant effluent is to be discharged, on the use made of the stream, on the policies and stipulations laid down by state authorities as based on the general conditions obtaining and on the type of treatment which best satisfies local requirements. Whatever may be the degree of treatment contemplated, the development of any project for sewage treatment with respect to capacity and effectiveness of the plant, as well as to its facility of operation when constructed, should aim to produce maximum results for the funds expended.

We are fast emerging from the stage of sewage treatment when plants were built, and then forgotten, when compliance with state requirements by the construction of treatment plants was considered a necessary but evil adjunct to the benefits of a sewerage system, and when the undertaking was seldom attended by a realization that faulty operation of such plants brought no return to anyone for the money spent in construction costs. This raising of standards, arising from a belated shouldering of responsibility for shortsighted fouling of streams, has been gradually developed through educational work and official action by health authorities, through intense and active interest in the subject shown by voluntary organizations such as the Isaac Walton League, and through an increased understanding by the public of the consequences of heedless discharge of raw or improperly treated sewage.

All of these influences, resulting in some states in the enactment of sewer rent laws to furnish funds for operation, have strengthened the demand for the efficient functioning of sewage treatment plants. Such efficiency of operation must be based, primarily, on the design of the plant. One of the principal bases for the granting of patents, for example, is the workability of the device proposed. Similarly, the practicality of any manufacturing business or financial plan must be assured if its success is to be guaranteed.

[1] *Presented at the Fall Meeting of the New York State Sewage Works Association, Schenectady, October 19, 1929.*

[2] *Consulting Sanitary Engineer, New York.*

So in the design of sewage disposal works it is not enough to provide for sufficient detention periods and the necessary reduction of velocity of flow in settling tanks to deposit suspended solids, if no means are included for satisfactory removal of these solids when they have accumulated in the bottom of tanks. Nor is there any use in building chlorinating tanks if inadequate arrangements are made for applying chlorine.

Plant design should therefore provide every arrangement possible for facility of operation, for effective treatment of sewage, and for observation and recording of results during each step of the process.

Of primary importance is some means for measuring the flow of sewage. Whether or not this should be done by weirs or by Venturi meters depends on the volume of flow to be treated. If weirs are used, automatic water level recorders should be installed in order that a continuous record of flow may be kept. Where chlorine is applied for sterilization of effluent or reagents are added to sludge to aid digestion or to hasten drying, the total flow and the fluctuations in flow must be on record if comparative economy of operation is to be studied and treatment costs reduced.

Preliminary screening, whether by bar or fine screens, is necessary for effective operation. In the case of bar screens, mechanical cleaning is one feature of design intended to relieve the operator of much manual labor and to give him more time to look after the main process. Drum and disk screens should be supplemented by bucket or belt conveyors to collect the screenings automatically. In the Bridgeport plant this is done by a system of pneumatic tubes.

Detritus or grit chambers should be so designed as to drop sand and grit but not organic matter. This is accomplished by regulating velocity through these chambers, either by varying the number of parallel chambers in use or by varying the flow level and the rate of flow by means of a change in the outlet section. Facilities for pumping out or draining individual grit chambers for removal of grit, or for continuous removal of grit by mechanical means, should be provided. At many plants grit forms a satisfactory and inodorous filling material.

With regard to the first major process in all sewage treatment plants, the reduction of suspended solids, it may be said, that nothing will take the place of decreasing the velocity of flow in passing the sewage through tanks for the purpose of depositing these solids. The design, therefore, should insure effective and even distribution of flow across the inlet end and sufficient length of flow for the curve of deposition to miss the outlet, if maximum results from the cross section and from the time of detention provided are to be produced. Within limits, effective sedimentation is a function depending on time as well as on low velocity.

As a factor in encouraging odor production, an inaccessible tank surface is very effective. Anyone familiar with disposal plants can almost smell

the solid concrete cover of a settling tank as soon as he sees it, knowing that scum is there in abundance and that just above the flow line, around the walls of the tank, is a fringe of organic matter putrefying and giving off hydrogen sulphide, secure from disturbance. If settling tanks cannot be housed with justifiable cost, they should be left open and accessible.

With the sedimentation of solids and the production of sludge the real problem begins. It was thought, when the septic tank was developed, that the sludge problem was solved: complete liquefaction of all organic matter and, perhaps, some magical metamorphosis of mineral matter into liquid form was expected to take place. This did not occur. Approximately a third to a half of the volume of sludge in septic tanks will be liquefied, but the remaining half to two-thirds is odorous and hard to handle. Imhoff tanks produce a sludge of less odor and one much more readily dried on sand beds. Separate sludge digestion, where justified by the requirements of plant location, furnishes a very positive and controllable method of sludge handling.

With any method of sludge production, the operator is dependent upon the facilities provided for drawing off sludge from the settling tanks. He should be assisted by hopper bottoms with slopes steep enough to secure concentration of sludge, or by a sludge collecting mechanism to thicken the sludge and draw it to a central point. Main sludge lines should be of ample size, not less than 8 inches in diameter. The operator should not be inconvenienced by any sludge line which cannot be rodded or flushed out when clogged. Precautions should be taken to prevent freezing of sludge lines in cold climates.

In separate sludge digestion plants means should be provided for the operator to draw off fully digested sludge from the digestion tank and for mixing this sludge with the incoming raw sludge, when necessary. Also, it is of considerable practical help to the operator, when it is necessary to bring the sludge in the digester back to the optimum pH value, if the reagents can be added to sludge in a separate sump on the suetion line of a pump so that thorough mixing of reagents, principally lime, may be assured by passage through a pump suction and impeller casing.

In any plant where the sludge piping system is complicated a piping and valve diagram should be prepared, and the letter or number designating each valve shown on the diagram should be cast into the manhole or valve box cover. In operating a plant no one can be expected to have X-ray eyes which will discern valves, tees and elbows ten or fifteen feet underground. Arrangements should be made in the design so that all sludge pipes may be flushed with water after use, or filled with water or with sewage if water under pressure is not available. Under certain conditions, waste cocks on sludge discharge lines from pumps are useful to permit sampling.

Provisions should be made for the ready handling of dried sludge or cake. This may not always be by overhead conveyors or by tracks, but whatever means for removal of cake from the beds are provided, the necessary lift and throw when cake is shoveled should not be made too great.

Any discussion on operation should not deal with elementary questions of design, but there are a few points in connection with the design of contact beds and trickling filters that are so involved with operation facilities that they should be mentioned. In the design of each of these types of works for secondary treatment hard filtering material should be specified, with the three dimensions of each piece of material as nearly equal as possible. There should be a sufficient number of units so that one unit may be cut out for resting or for cleaning or repairs without placing too much overload on the remaining units.

Siphon or dosing chambers should be of sufficient capacity, and siphons should have an adequate rate of discharge so that the operator will not be hampered by a dribbling or nearly continuous flow through the beds. Instead there should be positive cycles, with adequate resting empty periods, on which the success of the operation is based.

In contact beds, with, say, three fillings daily, the cycle should be approximately 1 hour for filling, $^3/_4$ hour for contact, $^1/_4$ hour for emptying and 6 hours for resting. The bed does its work largely in the resting empty period, and this should not be cut short.

In the design of trickling filters real assistance will be given the operator if provision is made for even distribution of tank effluent over the bed area and for a rest period for filter units to permit conditioning. Beds should not be too shallow, generally not under 5 feet in depth, but no advantage is gained by building trickling filters over 6 or 8 feet deep. Here, again, sufficient slope should be given to floors to permit ready flushing of deposited material to the outlets, and means should be provided for flushing and draining all distribution piping.

In the operation of sand filters full opportunity should be afforded to divert the flow of tank effluent in any quantity to any bed desired. It is believed that this can best be accomplished by the use of hinged sections of the side walls of the main distributing trough in conjunction with alternating dosing siphons.

Activated sludge plant operation would require a chapter by itself. This process produces a remarkable effluent, requires comparatively little plant site area, and may be safely contemplated at locations where odor prevention is an important consideration, provided the reduction of the sludge produced is handled without nuisance. The volume of the sludge, at 98 to 99 per cent moisture, is about five times that produced by sedimentation without aeration, chiefly because of the conversion of solids in solution to colloidal form.

Every treatment plant design for a plant receiving a considerable sewage flow should include a laboratory. Proper laboratory equipment and supplies for daily tests for residual chlorine, pH values, relative stability and suspended solids, semi-weekly presumptive tests for B. Coli on final effluent, biochemical oxygen demand and dissolved oxygen, and weekly sludge tests for total solids, ash, loss on ignition, pH values and, sometimes, for iron, will cost in the neighborhood of $500. The laboratory corner of the plant should have plenty of daylight and artificial light, should be provided with a sink of acid resisting material, hot and cold water and arrangements for heating. A cabinet with shelves and pigeonholes of the proper size to receive the accumulation of daily and weekly record sheets should be furnished.

To paraphrase an ancient writer, the well-supplied operator may say:

> My prayers with this I used to charge,
> A model plant, not overlarge,
> In which there should a test room be,
> Recorders, working ceaselessly,
> And where, to crown the whole, there should
> Be found a pipe plan, understood.
> All this and more, the gods have sent,
> And I am heartily content.

Status of Sewage Treatment in New York State

BY CHARLES A. HOLMQUIST[1]

The State Board of Health was established and organized under legislative enactment in 1880, but it was not until 1903 that the reorganized State Department of Health was given any specific control over stream pollution. Prior to 1903 nearly all of our municipalities and industrial plants discharged their sewage and wastes into the nearest stream or watercourse without any treatment and probably without much consideration as to the effect of such discharge upon the stream and communities below. This condition was due not only to the fact that it was the easiest and cheapest way of getting rid of the sewage and wastes but also because the principles underlying sewage treatment were not generally understood when the earliest sewer systems were installed. Relatively little was known, even by the medical profession, of the relation of public health to stream pollution. Only a few municipal sewage disposal plants had been constructed in this state prior to 1903, and these had been installed to prevent the creation of public nuisances within the municipalities. In fact, before the Engineering Division of the State Health Department was organized in 1906, relatively little was known, even by the Department, of the sanitary condition of the streams and public water supplies of the state.

One of the first duties imposed upon the Engineering Division was to make a thorough investigation of the principal watersheds of the state with special reference to stream pollution. In each case a very complete report was prepared setting forth the results of the sanitary survey of the watersheds, and giving in detail the sources, nature and extent of the pollution on each drainage area. This investigation formed the basis for outlining the policy followed by the Department in passing upon plans and issuing permits for sewerage and sewage disposal.

The so-called anti-pollution law, passed in 1903 and now part of Article V of the Public Health Law, prohibits the discharge of any sewage, sewage effluent, industrial wastes or any decomposable or putrescible matter of any kind, into any of the waters of this state in quantities injurious to public health without written permission from the State Commissioner of Health. This law gives the Commissioner of Health the authority to prohibit the discharge of untreated or raw sewage or industrial wastes from new projects, and it has been the consistent policy of the Department to require provisions for the construction of sewage treatment plants for all new sewer systems installed since that time. When plans have been approved for major sewer extensions to existing sewer systems in munici-

[1] *Director, Division of Sanitation, New York State Department of Health, Albany, N. Y.*

palities, the Department has required that adequate sewage treatment works be installed by a definite date, or that such works be installed and put in operation whenever the State Commissioner of Health deems it necessary. As a result of this policy, sewage treatment plants have been installed in over 150 cities and villages in this state. Many other cities are either constructing or planning to construct sewage treatment works.

The original anti-pollution law passed in 1903, however, did not give the Commissioner of Health well-defined authority to stop the discharge of untreated sewage, or industrial wastes from existing systems into the waters of the state. In fact, it expressly exempted existing systems from this obligation. Municipalities and industrial concerns that had sewer systems in operation prior to 1903, had apparently begun to look upon the discharge of untreated sewage or wastes from such systems as a vested right and seemed to resent any requirement or recommendations for the installation of sewage or waste treatment plants.

Realizing that under the provisions of the original act, it would be impracticable to clean up many existing cases of stream pollution and to protect some of our public water supplies derived from surface streams, the Department succeeded in 1911 in having a new section (*76a*) inserted in the Public Health Law. This section provides that if the State Commissioner of Health shall determine upon investigation that sewage or wastes are being discharged into any of the waters of the state in a manner injurious to or so as to create a menace to health or so as to create a public nuisance, he may, after a hearing, order the discontinuance of such discharge provided such order is approved by the Governor and the Attorney General. This section of the law, however, does not apply to refuse or waste matter from any shop, factory, mill or industrial establishment not containing sewage. Since this law went into effect the Health Department has succeeded not only in preventing the discharge of raw sewage from new or proposed systems, but in having sewage disposal works installed to care for the sewage of a great many sewer systems in operation prior to 1903.

There are about 343 sewerage systems in New York State at the present time. Some 292 of these are owned and maintained by municipalities or sewer districts. The systems are as a rule comprehensive and serve most of the built-up sections of the communities. Generally speaking, the private systems, of which there are fifty-one, serve only small portions of villages and were originally established to serve small groups of people who realized the need of better and safer methods of sewage disposal than those furnished by the ordinary cesspool. As the systems were extended and additional population wished to be served, sewer associations or companies were often formed. In a few villages in the state such companies have expanded until practically all of the built-up sections have been

served by sewer systems. The Department feels that such methods of establishing sewer systems are to be discouraged, since, in many instances, they follow no comprehensive plan, are often poorly constructed and provide no methods and offer little opportunity for the treatment of the sewage. The population served by such systems is relatively small compared with the total population of 8,800,000 which is now served by all sewer systems. The population so served represents about 78.8 per cent of the total population of the state.

In recent years the installation of sewage treatment plants has kept pace with the construction of sewer systems, and many cities and villages which have never treated their sewage are now installing plants not only to eliminate nuisances, but also as a matter of civic pride. There are now about 155 sewage treatment plants serving a population of 1,700,000, or about 20 per cent of the population served by sewer systems. About one-third of these plants provide simply for sedimentation, which is often sufficient treatment owing to the unusual opportunity for sewage dilution by the number of large streams and bodies of water throughout the state. In addition to the fifty plants providing sedimentation of the sewage, there are thirty other plants which have settling tanks with provision for chlorination of sewage effluent. They have received careful attention, have been operated under ortho-tolidine control, and have been very effective in their results. Daily records of operation are maintained and sent to the State Department of Health each month so that close coöperation between operators and the Department has been possible, to our mutual benefit.

The tendency in sewage treatment plant construction in this state seems to favor the continued use of trickling filters, rather than contact beds, as an integral part of the plant. There are now thirty municipal plants which use trickling filters in conjunction with settling tanks and other forms of treatment. These plants range in degree of treatment from plain settling tanks with trickling filters to such complete treatment as settling tanks, trickling filters, sand filters, chlorination and final settling tanks. Since 1925 twelve plants using trickling filters have been constructed and only one plant with contact beds. In fact, with the exception of the Pleasantville plant, which was built in 1925, all plants using contact beds were constructed between 1900 and 1915.

The use of sand filters as a supplementary form of sewage treatment is not uncommon in New York State. There are at present seventeen such installations, the first of which was made at Saratoga Springs in 1903. There are four unusual installations, all on Long Island, where filters are built on natural sand with no underdrains. The subsoil is of such a nature as to permit satisfactory absorption of the sewage effluent.

During 1929 two new activated sludge plants have been built, both

on Long Island, at Mineola and Rockville Center. The only other plant of this type, which is at Mamaroneck, was built in 1925. It will be abandoned in the near future when the Mamaroneck Valley trunk sewer, which will intercept the sewage now tributary to the plant, is completed.

The sewage treatment plants in this state represent the expenditure of many millions of dollars. Years ago municipal officials seemed to think that such plants would run themselves and that they needed no care and attention. Undoubtedly, similar beliefs are held today. At any rate, it is known that many plants are in need of better operation and supervision. As a result of special legislative enactment it was possible, a few years ago, for the State Health Department to obtain an appropriation for an engineer who could devote his entire time to the supervision of sewage treatment plants on Long Island. The present condition of these plants and the care given to their operation is sufficient testimony to the fact that proper supervision and operation will obtain efficient and satisfactory results.

The lack of attention to sewage treatment works is, in many instances, due to the fact that funds are not available or are not appropriated for their maintenance and operation. In order that such funds might be more easily obtained, the State Health Department sponsored bills at the last session of the Legislature permitting cities and villages to assess and collect sewer rents, which may be used only for the maintenance, operation and repair of the sewer systems and sewage treatment works. These bills, which provided for amendments to the village law and to the general city law, were passed by the Legislature and signed by the Governor. They are known as Chapter 225 and Chapter 678, respectively, of the laws of 1929. The village sewer rental law is as follows:

The board of trustees of any village which has installed or is installing for public use a sewerage system including some form of sewage treatment plant may establish by resolution a scale of rents to be called "sewer rents," to be paid at such times and in such manner as the board may prescribe. Such rents may be based upon either the metered consumption of water on premises connected with the sewer system, making due allowances for commercial use of water, the number and kind of plumbing fixtures connected with the sewer system or the number of persons served by said sewer system, or may be determined by the board of trustees upon any other equitable basis. The board of trustees may change the rates of such rents from time to time as may be deemed advisable. Such rents shall constitute a lien upon the real property served by sewers, and such a lien is prior and superior to every other lien or claim, except the lien of an existing tax, water rent or local assessment, and the board of trustees may bring and maintain an action in the name of the village for the foreclosure of such liens for such sewer rents. The funds received from the collection of sewer rentals shall be kept as a separate and distinct fund and shall be known as the sewer fund. This fund shall be used for the payment of the cost of the management, maintenance, operation and repair of the sewerage system including treatment and disposal works, and any surplus in such fund may be used for the enlargement or replacement of the same and for the

payment of the interest on any debt incurred for the construction of such sewerage system, including sewage pumping, treatment and disposal works, and for retiring such debt, but shall not be used for the extension of a sewerage system to serve unsewered areas or for any purpose other than one or more of those above specified.

It is believed that this is a definite forward step in solving stream pollution problems, and all engineers and plant operators are urged to encourage the adoption of "sewer rents."

Another attack on the stream pollution problem was advanced by the Governor of New York State when a committee was appointed to investigate the pollution of streams by sewage and wastes from state institutions. The State Commissioner of Health was appointed chairman of the committee, which included the State Superintendent of Public Works, the State Commissioner of Mental Hygiene and the State Commissioner of Correction. The investigation of the disposal of the sewage at the state institutions was made by the Division of Sanitation of the State Department of Health and was used as the basis of a report to Governor Roosevelt. Appropriation of funds will be asked of the State Legislature for the treatment of the sewage at these institutions.

Before concluding, mention should be made of the status of the pollution of streams by phenolic wastes. A few years ago the entire season's pack of peas of a cannery was spoiled due to objectionable tastes and odors caused by the pollution of the public water supply by wastes from a by-product coke plant. Various methods of eliminating the wastes were tried by the coke company with indifferent success. Finally a deep well was drilled in limestone, into which the ammonia-still liquor was discharged, after passing through a sedimentation tank and coke strainer, which removed lime and other suspended solids in the wastes. This well has operated now for over four years without a material reduction in its capacity and, so far as is known this practice has not resulted in the pollution of any ground or surface water supplies, or have any chloro-phenol tastes occurred in the public water supply below the plant.

At another by-product coke plant in New York State the ammonia-still wastes are coagulated with copperas, settled in a pressure sedimentation tank, filtered through pressure rapid sand filters and then discharged into four wells drilled to a depth of about 300 feet. These wells penetrate fresh water bearing strata, which were sealed off, and then penetrate a salt water bearing stratum into which the filtered wastes are discharged. This effective preliminary treatment was considered necessary to prevent the clogging of the water bearing stratum.

Other coke plants in this state recover phenol from ammonia liquors by means of benzol scrubbers and discharge the effluent into surface water streams under permits issued by the State Commissioner of Health.

A plant of Troy, New York, recovers about 95 per cent of the phenol in the ammonia liquors.

One by-product coke plant in this state discharges the ammonia still liquors into a municipal sewer system and sewage disposal plant consisting of Imhoff tanks. This method of disposal, which, of course, is a very economical one for the gas works, was permitted by the city only after extensive studies and experiments had shown that the discharge of ammonia still liquor into the Imhoff tanks in the proportion of 1 gallon of wastes to 1000 gallons of sewage (or twice the concentration expected to obtain in practice) had no deleterious effect on the sludge or on the operation of the Imhoff tanks. These tests and experiments failed to indicate that the contact of the wastes with the sewage produced any appreciable reduction in the phenol content of the wastes. However, the outlet of the disposal works is farther from the water supply intake and the dilution is greater than that at the original point of discharge of the wastes, so the local water supply problem has been solved.

In the near future it is proposed to expend over $50,000,000 on three large projects for the interception and treatment of sewage in New York State. The largest of these is the proposed activated sludge plant on Wards Island in New York City. The cost of intercepting sewers and tunnels to deliver the sewage to the plant will be about $12,000,000. The complete treatment plant will cost about $19,000,000, which includes a fertilizer plant and three sludge boats. This plant is designed to treat 180 million gallons of sewage daily and will serve a present population of 1,100,000, or about 20 per cent of the total population of the city. The second large project is the so-called South Buffalo project of the city of Buffalo and involves the expenditure of about $9,400,000 for collecting sewers, storm relief outlets, pumping station and sewage treatment works of the activated sludge type. These works when completed will care for the sewage from about one-third of the city. The third project, namely, that of the Westchester County Sanitary Sewer Commission, is for several million dollars for trunk sewers and sewage treatment works. This Commission has already completed large trunk sewer systems, has others under construction and other projects proposed.

Conditions in New York State indicate that there is a growing demand on the part of the public for cleaner streams, and that this demand is being met is clearly reflected in the number of sewage and waste treatment plants which are being installed.

Powers and Duties of Massachusetts State Authorities in Relation to Establishment and Operation of Sewage Treatment Plants[1]

BY EDWARD WRIGHT[2]

Mr. X. H. Goodnough, Chief Engineer of the Massachusetts State Department of Health, who has long been conversant with the disposal of sewage in Massachusetts, was asked to prepare this paper, but owing to his inability to be present at this meeting (New England Sewage Works Association), he has asked the writer to prepare the paper and to present it.

The Massachusetts state government is divided into three general divisions—legislative, executive and the judiciary. This paper will be confined to the activities of the first two divisions of the state government rather than the latter, as there have been comparatively few Supreme Court decisions relating to the powers and duties of the state on sewage treatment works.

The first act delegating authority to the State Board of Health in this matter was Chapter 274 of the Acts of 1886, giving the State Board of Health the general oversight and care of all inland waters. This act with a few changes now appears as General Laws, Chapter 111, Sections 17 and 159. Section 17 of Chapter 111 of the General Laws is as follows:

> SECTION 17. The department shall consult with and advise the officers of towns and persons having or about to have systems of water supply, drainage or sewerage as to the most appropriate source of water supply and the best method of assuring its purity, or as to the best method of disposing of their drainage or sewage with reference to the existing and future needs of other towns or persons which may be affected thereby. It shall also consult with and advise persons engaged or intending to engage in any manufacturing or other business whose drainage or sewage may tend to pollute any inland water as to the best method of preventing such pollution, and it may conduct experiments to determine the best methods of the purification or disposal of drainage or sewage. No person shall be required to bear the expense of such consultation, advice or experiments. Towns and persons shall submit to said department for its advice their proposed system of water supply or of the disposal of drainage or sewage, and all petitions to the general court for authority to introduce a system of water supply, drainage or sewerage shall be accompanied by a copy of the recommendation and advice of said department thereon. In this section the term "drainage" means rainfall, surface and subsoil water only, and "sewage" means domestic and manufacturing filth and refuse.

It has been ruled that the use of the word "towns" in the above section refers to all municipalities.

[1] *Presented at the Fall Meeting of the New England Sewage Works Association, Worcester, Mass., Oct. 21, 1929.*

[2] *Associate Sanitary Engineer, Massachusetts Department of Public Health.*

The Department of Health is directed by this act to consult with and advise persons in authority as to sewerage and sewage disposal. The act also provides that the Department may conduct experiments in the treatment of sewage and objectionable wastes, which in the beginning resulted in the establishment of the Lawrence Experiment Station, with which we are all familiar. It provides also for the submission of plans of sewage treatment works to the Department for its advice.

Section 5 of Chapter 111 of the General Laws provides that the Department of Health "shall annually examine all main outlets of sewers and drainage of towns of the Commonwealth, and the effect of sewage disposal," and other sections of General Laws provide for reporting annually to the Legislature on this general subject.

General Laws, Chapter 83, Section 6, provides that a city or town may take land within its limits for the treatment, purification and disposal of sewage, with the approval of the Department of Public Health after a public hearing.

With the exception of the latter provision, it will be noted that the powers and duties of the Department of Public Health are largely advisory. This is the case when a city or town is able financially to proceed with the construction of sewerage and sewage treatment works without borrowing money in excess of the limit of indebtedness. In Massachusetts the limit established for towns is 3 per cent of the total assessed valuation and for cities $2^1/_2$ per cent of the total assessed valuation. In obtaining legislative authority to borrow outside the debt limit special acts of the Legislature are required, and the Legislature has invariably included a section in these acts providing that no action shall be taken under the special act until the plans for the system of sewerage and sewage disposal have been approved by the Department after a hearing. These special acts generally provide that the plans submitted to the Department shall show all the work to be done, and that a hearing shall be held by the Department after due notice to the public. No municipality has of late been able to finance any substantial sewerage system and sewage disposal works, except under special legislative authority, and by this means the Department has been given almost complete control over the type of sewage treatment works to be constructed.

General Laws, Chapter 83, Section 6, also makes the following provision:

> "...Towns or persons owning or operating filter beds or other works for the treatment, purification and disposal of sewage shall provide and maintain works adequate for the treatment of the sewage at all times, and shall operate such works in such manner as will prevent a nuisance therefrom or the discharge or escape of unpurified or imperfectly purified sewage or effluent into any stream, pond or other water or other objectionable result."

Portions of this section have been brought before the Supreme Court, but there have been no decisions of particular interest in the question at hand.

In 1908 and 1909 there were certain municipal sewage treatment works which were inadequate in capacity and which were operating in an inefficient manner. In 1909, an act was passed which gave the Department considerable additional authority relative to filter beds or other works for the treatment, purification or disposal of sewage. The portion of this act which applies is Section 7 of Chapter 83 of the General Laws, and is as follows:

> If the department of public health determines upon examination that a filter bed or other works for the treatment, purification and disposal of sewage causes the pollution of a stream, pond or other water or is likely to become a source of nuisance or create objectionable results in its neighborhood by reason of defective construction, inadequate capacity or negligence or inefficiency in maintenance or operation or from other cause, it may issue notice in writing to the town or person owning or operating such works requiring such enlargement or improvements in the works or change in the method of operation thereof as may be necessary for the proper maintenance and operation of the works and the efficient purification and disposal of the sewage. . . .

This portion of Section 7 has been of considerable value in a number of instances where investigations have shown that the sewage treatment works were inadequate for the proper treatment of the sewage.

Another part of Section 7 has to do with the discharge of certain substances into the sewers which may interfere with the operation of the sewage disposal works, and this section is as follows:

> . . . If said department determines after investigation that the unsatisfactory operation of a sewage disposal system is due wholly or partly to the discharge into the system of manufacturing waste or other substance of such character as to interfere with the efficient operation of said works, it may if necessary prohibit the entrance of such waste or other material, or may regulate the entrance thereof into the system, or may require the treatment of such waste or other material in such manner as may be necessary to prevent its interference with the operation of the works.

This portion has been of value in a number of instances, particularly in one case where alcoholic wastes from the manufacture of yeast were found to entirely upset the biological treatment of the sewage by sand filtration and it became necessary to require the treatment of these wastes before they were discharged into the sewers. A somewhat similar provision is also contained in Chapter 83 of the General Laws, Section 10, relative to local regulations of the use of the sewers:

> The aldermen of a city or the sewer commissioners, selectmen or road commissioners of a town may make necessary regulations regarding the use of common sewers to prevent the entrance or discharge therein of any substance which may tend to interfere with the flow of sewage or the proper operation of the sewerage system or disposal

works, and may make regulations for the construction and use of particular sewers, and impose penalties not exceeding twenty dollars for their violation.

The Department of Public Health through its Engineering Division carries on as much inspectional work of sewage treatment plants as means and time allow. Most of the larger sewage treatment plants are examined on an average of ten times per year and records are kept of the general condition of these works. In this connection estimates are made of the quantity of sewage discharged to the works and other records are kept of the distribution of the sewage on the various filter beds, the withdrawal of sludge from the sedimentation tanks and other operating data. In addition, samples for analysis are collected once a month by the operators of the various sewage disposal works or representatives of the department. These samples are collected from the raw sewage, settled sewage and final effluent, and in the more complicated works additional samples are collected at various stages of treatment. It is quite difficult to have these samples collected in composite parts excepting at the larger plants where men are retained for this purpose, though in most of the larger plants samples are collected in three or four or more composite parts so as to get reasonably representative samples.

The Department also obtains information annually as to the length of sewers tributary to the various sewage disposal works and as to the number of connections. This information is compiled at the end of the year, and since 1911 the Department has annually published the results of the analyses of sewage, settled sewage and effluent at the larger municipal works, together with the information as to the average quantity of sewage, rate of operation, number of miles of sewers, number of connections, and all other pertinent data. In addition, the Department has generally made a brief annual statement as to the efficiency of the larger municipal treatment works and also a brief statement as to the effect of the effluent or untreated sewage on the stream into which it is discharged.

The Department, upon application, advises cities and towns as to changes in methods of operation or improvements in the construction of sewage disposal works. Information obtained by the routine inspectional work is of considerable value in the preparation of reports and advice on these matters.

One other phase of the sewage disposal question in Massachusetts, which of late has required considerable attention of the Department, is the design and construction of institutional sewerage systems and sewage disposal works. The Department has of late been required to construct a sewerage system and sewage disposal works at Lakeville State Sanatorium and at the Pondville Hospital and has made designs for the collection and treatment of the sewage of the Concord Reformatory and the Prison Camp and Hospital at Rutland. The Department is now engaged in the

preparation of plans and estimates for sewerage and sewage treatment works at the new State Prison at Norfolk, the Industrial School at Shirley and at certain institutions at Rutland.

The act under which the Worcester disposal plant was constructed is worthy of notice. Before and during the war the existing sewage disposal works at Worcester became inadequate for the proper treatment of the sewage, and some of the members of the Legislature residing in the valley below Worcester proposed rather drastic legislation which eventually after many hearings, became law. This appears as Chapter 171 of the Special Acts of 1919 and is perhaps as drastic legislation on sewage disposal as has ever been passed by the Massachusetts Legislature. This act is as follows:

SECTION 1. The City of Worcester shall, before the first day of April, nineteen hundred and twenty-four, remove from its sewage, before it is discharged into Blackstone River, the offensive and polluting properties and substances therein, so that after its discharge into said river, either directly or through its tributaries, it shall not create a nuisance or endanger the public health. The city shall have power to take, or to acquire by purchase or otherwise, any lands, water rights, water privileges, rights of way or easements in the said city or in the town of Millbury, necessary for the establishment of a system of sewage disposal. The city shall, on or before the first day of October, nineteen hundred and nineteen, begin the work of constructing a new sewage disposal plant in accordance with plans to be approved by the State Department of Health, and shall complete said work on or before the first day of April, nineteen hundred and twenty-four. For the purpose aforesaid, the city shall, before the first day of April, nineteen hundred and twenty, expend not less than one hundred thousand dollars, and not less than two hundred thousand dollars each year thereafter until the said plant is completed. Failure on the part of the city to comply with the provisions of this section shall be *prima facie* evidence of negligence on its part in any action for nuisance or damages brought against the city on account of its sewage disposal.

SECTION 2. The Supreme Judicial Court or the Superior Court shall have jurisdiction in equity upon an information filed by the Attorney-General, acting upon the request of any town situated on Blackstone River and asserting the existence of a nuisance under this act, to restrain, enjoin or abate the same as a common nuisance; but nothing herein contained shall be construed to restrict or limit the rights of any municipality, public board, department, state officer or individual to any other legal remedy.

SECTION 3. The State Department of Health shall from time to time, as often as it may deem necessary, examine the sewage and effluent of the Worcester sewage system and disposal works, and the bed, banks and waters of Blackstone River or any tributary thereof, at such point or points, as the Department may elect, to determine the character and condition of said sewage and effluent and of the river or its tributaries, and may make such measurements of the flow of the same as it may deem necessary. A summary of the results of these observations shall be furnished from time to time in writing to the Mayor of Worcester. Copies of records of observations made by said Department of the quantity and character of sewage and effluent discharged from the sewerage works of the City of Worcester and of observations of the flow of Blackstone River and of the condition of its bed, banks and waters, together with the substance of action by the Department relative thereto, shall be published in the annual report of

the Department. Whenever, in the opinion of said Department, the quantity of obnoxious or offensive substances contained in any sewage or effluent discharged not said stream from the sewerage works of the City of Worcester is such as to create a nuisance therein or to injure the public health, the said Department shall give notice in writing to the mayor of the said city, and shall direct such changes in the sewerage system and disposal works as it may deem necessary. Failure on the part of the said city to comply with the direction and orders of the said department within such reasonable time as the department shall determine shall be *prima facie* evidence of the existence of a nuisance under the provisions of this act.

SECTION 4. The plans and locations of additions to the sewage disposal works of the said city shall be subject to the advice and recommendation of the State Department of Health, as provided in existing general laws.

The most drastic part of this act, it will be noticed, is contained in Section 1 where the city is ordered to expend a certain sum of money for sewage disposal purposes within a certain limited time. The act also authorizes the Department to direct such changes in the sewerage system and sewage disposal works as it may deem necessary. Upon the passage of this act the city immediately proceeded with the construction of adequate sewage treatment works, and at present this plant is the largest in Massachusetts.

Activated Sludge at Worcester, England.—Mr. Percy Lamb has described the activated sludge plant at Worcester, England. The sewage reaches the plant through an inverted siphon 84 ft. deep. Detritus is pumped from the bottom of the well, and "box" coarse screens operate at 65 ft. depth. There are four aeration tanks of different design, all 18 ft. deep. The average flow treated is about 2.5 million gallons per day. At the maximum rate of 6 m. g. d. the aeration period is 4 hours. The air consumption is 1.25 cu. ft. per gallon. The settling tanks, 21 ft. deep, have hopper bottoms, from which settled activated sludge is drawn by hydrostatic head through 6-in. pipes. Use of air lifts would have been preferable. The volume of sludge in the aeration tanks has averaged 10 per cent, after one hour's settling. Sludge has been run onto sloping sand beds but some nuisance has resulted. A lagoon 270 by 210 by 8 ft. deep has been used for disposal of sludge. The plant has been in operation since August, 1927.—*Proc. Assn. Managers of Sewage Disposal Works*, pp. 136-139, 1928.

Sewage Disposal in Connecticut from a State Standpoint[1]

BY WARREN J. SCOTT[2]

There are two main considerations in the field of sewage disposal, both with some common aspects.

The first is the effect on health of improper sewage disposal, such as pollution of public water supplies, pollution of bathing beaches, pollution of shellfish grounds and creation of gross nuisances. Although, in many instances, the creation of nuisance may not directly affect health by causing specific sickness, it may affect the general welfare or the health tone of the community.

The second consideration is that of economics and the general welfare from a broader standpoint, not directly allied with health. This includes: the effect of improper sewage disposal on streams which may be used for future domestic water supplies; usability of streams for industrial water supplies; destruction of fish life; the aesthetic aspect of the appearance and odor of streams; and perhaps interference with navigation from sewage sludge deposits.

In Connecticut there is at the present time no public water supply receiving discharge from any public sewerage or wastes disposal system. This has resulted from the location of most of our large cities and towns in the valleys of our large rivers or along the shore and the relatively easy and inexpensive method of obtaining water, mostly by gravity, from upland streams in sparsely populated areas. The fact that no public water supplies have been as yet affected by sewage discharge has unquestionably retarded state-wide sewage treatment, but substantial progress has been and is being made to clean up the waters of the state. Many sewage treatment plants were constructed in the past over a long period of years, either because of necessity occasioned by threatened or consummated civil damage suits by downstream property owners, or because of community desire to protect bathing areas or avoid nuisance conditions. Notwithstanding such accomplishments, need for speedier improvement has existed.

I will not burden you with the history of numerous investigations of stream pollution in Connecticut, which have been carried out by the State Board of Health, the Industrial Wastes Board and other special commissions. All have undoubtedly quickened the public desire for better conditions in our streams and shore waters. They led in 1925 to the creation of the State Water Commission by legislative act.

[1] *Presented at First Fall Meeting, New England Sewage Works Association, Worcester, Mass., October 21, 1929.*

[2] *Director, Bureau of Sanitary Engineering, Connecticut State Department of Health.*

The State Water Commission is composed of three members appointed by the governor with the consent of the senate and this commission was granted wide powers to control pollution of waters. The term "pollution" as defined in the enabling act means any mingling of polluting material with water. No degree of pollution is specified. The State Water Commission was given the power to order abatement of pollution after proper hearings. The law provides that action by the commission may be taken upon its own initiative. The State Water Commission may require any firm, person or corporation (including municipalities and industries) to use or to operate some practicable and reasonably available system or means which will reduce, control or eliminate pollution, having regard for the rights and interests of all persons concerned, provided the cost of installation, maintenance and operation shall not be unreasonable or inequitable. The order must specify the particular system or means to be used or operated, provided that if there is more than one practicable and reasonably available system or means, the order must allow the person, firm or corporation affected the right to choose which system or means to adopt. In the latter case, the project must be approved by the State Water Commission. The law further provides for appeal to the superior court from an order of the commission and prohibits the establishment of any new source of pollution without approval by the commission. The commission does not exercise control over public water supplies, the sanitary supervision of which comes under the jurisdiction of the State Department of Health.

When the law creating the State Water Commission was passed, the existing laws giving the State Department of Health certain powers and duties relating to sewage disposal were left unchanged. These laws in effect permit the State Department of Health to require changes in sewage disposal conditions where necessary for the protection of the public health, delegate to the State Department of Health, the duty of supervising the operation of public sewage treatment plants, and specify that plans for new public sewage treatment plants must be approved by the State Department of Health. In 1929, the existing laws were altered somewhat but without changing the status of the situation except to state specifically that plans for new public sewage treatment plants must be approved both by the State Department of Health and the State Water Commission.

It may be said, therefore, that in Connecticut we now have two state supervisory bodies interested in sewage disposal—one from the standpoint of health alone and the other from the standpoint of the remedy of pollution which affects economic and general welfare conditions. Close coöperation has existed between the two bodies so as to minimize overlapping. Plans are approved by what is close to joint action. Con-

ferences on new plans are held by the respective chief engineers and any points of difference are ironed out before formal action is taken.

The State Department of Health is charged with sanitary supervision of shellfish areas and is also greatly concerned with pollution of bathing beaches. During the summer of 1929 an engineer was employed temporarily on a comprehensive study of salt water bathing beaches along our shores. About half of the shore areas were covered and it is hoped that the work may be completed next summer. The results of these studies will be that not only will the State Department of Health be far better informed as to the relative degree of safety of bathing beaches but also the department should be able to induce action by local authorities to eliminate danger spots by installation of sewage treatment.

The state policy with regard to operation and establishment of sewage treatment plants requires that periodic inspections of treatment plants be made by an engineer from the State Department of Health. Copies of reports of inspections are forwarded to local officials in charge and the general conditions at each treatment plant are summarized each year in the annual report of the department. Where routine inspections of operating conditions by the State Department of Health disclose that certain minor changes are necessary, recommendations are made to the local authorities and are almost always carried out, although some difficulty is experienced with changes in city administrations. The department has recently been making comprehensive surveys of individual plants and these surveys sometimes reveal striking faults or inadequacies in a plant. It is then recommended that a consulting engineer be employed to survey the situation in detail and present to the local authorities a plan of action with cost estimates.

Where no treatment plants exist, the policy of the State Water Commission has been to endeavor to induce the local authorities in a similar way to authorize the carrying out of an engineering survey of the sewage system in order to obtain data as to possible methods of treatment and the cost of construction of treatment works. The State Department of Health has tried to coöperate in this work.

In order to bring things to a definite head, it has been found that a round table conference between local and state authorities has been the most satisfactory procedure. The state usually requests the conference and all local officials interested are invited. The cards are then all placed on the table—the existing conditions, methods of improvement and ways of financing. Such conferences have produced far-reaching results.

The cost of the engineering study, whether with regard to an existing treatment plant or a new project, can usually be met by current funds either with or without approval by the voters at a special town meeting. After the cost estimates are in, the next step is to set in motion machinery

to raise the funds, provided the project is approved locally. Where the expenditure is large, it is sometimes possible to divide the project into two steps, the immediate one being perhaps the construction of intercepting sewers and primary treatment, and the later one the installation of secondary treatment.

In the case of an entirely new sewerage system and treatment plant, the cost is sometimes met partly by regular sewer assessments and partly by a bond issue. New treatment plants for existing systems are usually financed by bond issues.

In Connecticut, the bonded indebtedness for all purposes in any city or town may not exceed five per cent of the grand list except by special permission from the state legislature, which is seldom granted. The charters of practically all the cities and towns require legislative approval of bond issues to finance sewerage projects, as well as votes by the city or town. The motive power behind requests for authorization to issue bonds for sewage disposal projects is usually furnished by the state authorities, sometimes with strong local backing, seldom entirely by local initiative.

The State Water Commission has as yet issued no summary orders that I know of, but its policy of coöperation and persistent pressure is bringing results. The public, too, is becoming more and more interested in the subject of sewage treatment. The result has been that practically every city or large town in the state, where no sewage treatment or inadequate sewage treatment has existed, is at some stage on a program of improvement. We feel in Connecticut that in the field of sewage treatment, things are "looking up."

Disposal of Sewage and Trade Wastes[1]

From the Standpoint of the Connecticut State Water Commission

BY WILLIAM R. COPELAND[2]

Mr. Scott has pointed out the principal features embodied in the law which created the State Water Commission of Connecticut. He emphasized the fact that the principal duties of the Department of Health, so far as stream pollution is concerned, have to do with matters pertaining to public health, whereas the duties of the Water Commission are more particularly concerned with economic problems.

Clauses in the law which created the water commission prescribe that the commission shall specify the type of processes which it advocates for the treatment of sewage and trade wastes; that the methods must be reasonable, both in regard to type of work performed and cost for construction and operation; and that the person, firm, or industry concerned has the right of appeal to the Supreme Court of Connecticut against the order of the commission. The law does not set any specific date when the various sources of pollution that now exist shall be eliminated, but stipulates that the commission may set the date.

Owing to the fact that the treatment of trade wastes, and the construction and operation of sewage disposal plants for handling sewage, often require the expenditure of large sums of money, the State Water Commission has found that it is very difficult to get private individuals, industrial plants and municipalities to undertake the financial burden.

It also should be noted that clauses in the Connecticut State Law limit the expenditure that may be made by towns and municipalities to sums such that, when all outstanding public obligations are added, the total annual expenditure shall not exceed five per cent of the grand list. Owing to the fact that bonds issued for the construction of various public works including pavements, parks, schools and the like, have in most cases been sold in such quantities that they have absorbed the funds available under this five per cent clause, it gives the local officials an excellent opportunity to delay the construction of sewage disposal works on the ground that they are prohibited by law from issuing the necessary funds.

In order that conditions of this sort may be improved, and to provide sufficient funds for the operation of such works after construction, it is very desirable that all members of this organization who are interested in the question of sewage disposal should unite in a movement looking toward the passage of laws that put sewers and sewage disposal plants in the class of "public utilities."

[1] *Read at First Fall Meeting, New England Sewage Works Association, Worcester, Mass., October 21, 1929.*

[2] *Sanitary Engineer, Connecticut State Water Commission.*

Municipalities are allowed to issue bonds for the construction and operation of water works in excess of the sum covered by the five per cent limit. The underlying reasons for exempting public utilities from the limitations placed by the 5 per cent clause are that the utilities earn sufficient money to pay the interest on the bonds and to retire the bonds without making it necessary to increase the tax levy. It is desirable that sewers and sewage disposal works should also be considered as public utilities.

In order to establish sewers and sewage disposal plants as a public utility the State of Ohio passed a law in 1923 (Amended Senate Bill No. 93) which includes the following provisions:

An Act to permit municipalities to assess and collect charges for the use of sewers and to provide for the proper maintenance, operation and control of sewerage systems and sewage disposal works, and to amend Section 4357 of the General Code.

Section 1. The council of any city or village which has installed or is installing sewerage, a system of sewerage, sewage pumping works or sewage treatment or disposal works for public use, may by ordinance establish just and equitable rates or charges of rents to be paid to such city or village for the use of such sewerage, a system of sewerage, sewage pumping works or sewage treatment or disposal works by every person, firm or corporation whose premises are served by a connection to such sewerage, system of sewerage, sewage pumping works or sewage treatment or disposal works. Such charges shall constitute a lien upon the property served by such connection and if not paid when due shall be collected in the same manner as other city and village taxes. The council may change such rates or charges from time to time, as may be deemed advisable. Provided, however, that in a municipality operating under a municipal charter the council or other legislative body may establish the schedule of rates herein authorized and provide for its administration by designating the department or officer of the municipality to be charged with the enforcement of the provisions of this act....

Section 5. The funds received from the collection of sewer rentals shall be deposited weekly with the treasurer of the corporation. Money so deposited shall be kept as a separate and distinct fund and shall be known as the sewer fund. When appropriated by council, it shall be subject to the order of the director of public service of a city or board of trustees of public affairs of a village. Such director or board shall sign all orders drawn on the treasurer of the corporation against such fund. This fund shall be used for the payment of the cost of the management, maintenance, operation and repair of the sewerage system and sewage pumping, treatment and disposal works and any surplus in such fund may be used for the enlargement or replacement of the same and for the payment of the interest on any debt incurred for the construction of such sewerage system and sewage pumping, treatment and disposal works, and for the creation of a sinking fund for the payment of such debt, but shall not be used for the extension of a sewerage system to serve unsewered areas or for any other purpose whatsoever.

The exact amounts and forms of such payments vary in the several towns and cities where such law is now in force, as illustrated in ordinances of the Village of Oxford, where the water is metered, and the City of East Palestine, where the water is sold on a flat rate.

For Metered Service:

An ordinance establishing the rates or rents to be paid to the village of Oxford, Ohio, for the use of the sewerage system and the sewage treatment and disposal works by every person, firm, corporation or institution whose premises are concerned in connection with such system of sewerage and sewage treatment and disposal works.

Section 1. That there be and is hereby established the rents or charges to be paid the village of Oxford, Ohio, for the use of the sewerage system and sewage treatment and disposal works by every person, firm, corporation or institution whose premises are served by a connection to such sewerage system and sewage treatment and disposal

works as follows: A rental equal to twenty-five (25c) cents per 1000 cubic feet of water consumed per quarter year, with a minimum charge of $1.25 per quarter year for each sewer service connection from each premise to the sewerage system.

For Flat Rate Service:

WHEREAS, the council of the City of East Palestine, Ohio, do now find, determine and declare it to be necessary and conductive for the public welfare and convenience and for the protection of the public health and safety to levy and collect an annual charge or rent upon lots and premises served by sewage connections with the Sanitary Sewer System, to pay the costs and expense of maintaining and operating the Sanitary Sewer System and Sewage Disposal Works of the City of East Palestine, Ohio.....

Section 111. To pay the cost and expense of maintaining and operating the sanitary sewer system and sewage disposal works of the City, that there be and is hereby levied upon each lot and premises on which is located, or any building which may hereafter be located on any lot or premises, any building which now has or may hereafter have installed therein any group of conveniences and which has installed therein the whole or any part of the group of conveniences and which are connected with a sanitary sewer system, a direct annual charge in the following sums to wit:

a. Any building or any premises occupied as a residence, and suites, apartments and rooms occupied and used as private living quarters two dollars per year for each group of conveniences therein.

b. Any building or any premises used as a factory, store, theater, lodge room, hotel and all other buildings two dollars per year for each group of conveniences therein.

c. That any building or part of building used as a laundry, milk depot, ice cream factory, soda fountain and all other industries of like nature having a large quantity of sewage now entering and hereafter to enter into the sanitary sewer system two dollars per year for each eight thousand (8000) gallons or part thereof of water consumed per quarter as shown by water meter or estimated by the Director of Public Service.

d. Any building or part of building not designated herein two dollars per year for each group of conveniences.

e. Provided that the municipal buildings, public school buildings and township buildings having connections and conveniences therein are hereby exempt from said payment of said charge or rent.

If the New England States could get laws of this character passed by the legislatures, all of the men who are interested in the construction and operation of sewage works would find that a practical method of obtaining the necessary money to build and operate the works can be procured without making it necessary to secure special legislation, and furthermore the new laws would relieve the local politicians of the distasteful duty of asking their fellow citizens to increase their taxes.

State Control of Sewage Disposal and Pollution of Public Waters in Rhode Island[1]

BY ESKIL C. JOHNSON[2]

For many years prior to 1920 efforts were made to obtain legislation to control the increasing pollution of the public waters in Rhode Island. Pollution of shellfish areas and of public water supplies was prohibited but authority to require the installation of sewage treatment plants was not vested in any state department. With the growth of Providence as an oil port, the damage resulting to the oyster industry, to boats, bathing beaches and private property from oil spills finally became so serious that the General Assembly in 1920 passed an act prohibiting pollution of the public waters and creating a special board of three men to administer the provisions of the act. This Board, known as the Board of Purification of Waters, began to function September 1, 1920.

The law is quite broad in its interpretation of what constitutes pollution and in the administrative powers granted to the board. Pollution is defined in the act as "the entrance or discharge of sewage into any of the waters of the state in such quantity as to cause or be likely to cause either by itself or in connection with other sewage so discharged, damage to the public, or to any person having a right to use said waters for boating, fishing or other purposes, or owning property in, under or bordering upon the same." The term "sewage" includes "any human or animal excremental liquid or substance, any decomposed animal or vegetable matter, garbage, offal, filth, waste, chemicals, acid, dyestuff, starch, coloring matter, oil and tar, and any compound, solution, mixture or product thereof, and every substance which may be injurious to public health or comfort, or which would injuriously affect the natural and healthy propagation, growth or development of any fish or shell-fish in the waters of this state, or of the nourishment of the same, or which would injuriously affect the flavor, taste or value as food of any such fish or shell-fish; or which would injure or defile any vessel, boat, wharf, pier or any public or private property upon, in or under said waters, or any shore thereof."

Jurisdiction

All tidal waters within the state and all inland waters of any river, stream, brook, pond or lake come under the jurisdiction of the board. This jurisdiction does not apply, however, to the sewage of the City of Newport or Town of Jamestown discharged through their respective sewer outlets; nor does it apply where the sole damage caused is rendering

[1] *Read at First Fall Meeting, New England Sewage Works Association, Worcester, Mass., October 21, 1929.*

[2] *Engineer, Rhode Island Board of Purification of Waters.*

the waters unsuitable for drinking purposes or ice supply, since the authority to prevent pollution of public water supplies is vested in the Public Health Commission.

Powers and Duties

The board is authorized and directed to regulate or prohibit the pollution of the waters of the state in accordance with the provisions of the act. If the board has reasonable cause to believe that any person is polluting, or if complaint is made to it that such is the fact, it is the duty of the board to investigate. For the purpose of investigating any complaint of pollution the board may hold public or private hearings, summon witnesses and take testimony under oath.

The board may require any person, having any sewer or system of sewers discharging into the waters of the state or upon the shores thereof, to submit a statement describing all such sewers, including the size, volume and character of sewage discharged from each, together with an adequate description of any works or methods employed to purify the sewage. The contents of such reports cannot be disclosed except by written permission of the person making the report. Upon request of any person discharging sewage into any of the waters of the state the board is required to consult with and advise such person as to the best practicable and reasonably vailable system or means to prevent such sewage from causing pollution.

The board has also full power to inspect and make orders regulating all methods and devices employed on any steamer or vessel used for the transportation of petroleum, gasoline, kerosene, tar or oil or any product or mixture thereof; it may also establish rules and regulations to prevent the discharge or escape of any of said substances into the public waters.

Before any person can be found guilty of pollution the board must grant such person a hearing at which evidence and witnesses, in behalf of the person alleged to be polluting, must be heard.

After due notice and hearing if the board shall find a person guilty of pollution it may enter an order directing such person to adopt or use or to operate properly, as the case may be, some practicable and reasonably available system or means to prevent such pollution, having due regard for the rights and interests of all persons concerned. The order may specify a particular system or means to be adopted, used or operated, but where there is more than one such system the person complained of may choose the system he desires. Unless the order specifies the means to be adopted, a plan or statement describing the proposed system must be submitted to the board before the installation is made, and later if any substantial changes are to be made a plan or statement describing such changes must be submitted.

Upon application of any person the board may enter an order approving

any system or means which he has adopted or may desire to adopt. Proper operation of an approved system constitutes compliance with all orders of the board as long as the order of approval remains unrevoked or unmodified.

Under the law no person may be prosecuted for polluting the waters of the state or at the instance of the state enjoined from such pollution unless he has violated an order of the board. Pollution in violation of any such order is punishable by a fine of not more than five hundred dollars, or by imprisonment for not more than one year, or by both such fine and imprisonment; each month or part thereof during which pollution in violation of an order of the board is repeated or continued is a separate and distinct offense.

Any person aggrieved by any order of the board against such person may appeal to the supreme court for a reversal thereof on the ground that the same is unlawful or unreasonable.

Policies

The general policy of the board has always been to attack the various pollution problems by seeking the coöperation of the parties causing the pollution. Efforts have been directed particularly toward the elimination of the larger factors of pollution, such as the discharge of large volumes of raw or incompletely purified sewage or waste liquors into the public waters by municipalities and manufacturing concerns. Conferences have been held at intervals with representatives of the major offenders with the object of arriving at satisfactory plans to correct conditions. Municipalities discharging sewage without treatment into the public waters have been urged to make preparations for installation of adequate treatment plants; where the treatment systems were inadequate, construction of such additions as might be necessary have been requested. In each case the board has tried to secure voluntary action on the part of the party causing the pollution. Proceedings to compel installation of adequate treatment facilities have been instituted only when the efforts of the board to obtain coöperation have been unsuccessful.

The board has always coöperated with municipalities and others endeavoring to solve their pollution problems, in so far as the limited personnel and funds of the board have permitted. All the available data relating to the individual problems which the board has collected has been made available to the engineers employed to design the treatment system.

In the opinion of the board, each municipality should endeavor to solve its own problems concerning methods of treatment. The question of whether the municipality should treat its sewage in its own plant, or should combine with other municipalities in construction of a joint treatment system, can best be determined by the municipality itself.

Manufacturing concerns, located on the banks of the streams, and isolated so far as connection to a municipal system is concerned, have likewise been requested to coöperate with the board by providing treatment for their wastes. Where a municipal sewer system is available, connection to that system is usually advised unless the volume and character of industrial wastes would put an undue burden upon the disposal system. The final determination as to whether or not such wastes, either with or without preliminary treatment, should be taken into the municipal sewers, however, properly lies with the local authorities.

A program to eliminate minor sources of pollution, such as drains and waste outlets from summer cottages and buildings, has been instituted recently by the board. The owners of residences located in close proximity to oyster growing areas and bathing beaches, have been requested to remove overflow pipes from cesspools or septic tanks and all pipes discharging untreated toilet wastes into the public waters. Assistance in solving any unusual problem is extended to any person making such request to the board.

The original members appointed to the board have been reappointed from time to time and thus there has been a continuity of policy and investigation since the board was established. Surveys and studies to determine sources of pollution, efficiency of operation of sewage treatment plants and condition of the various streams and tidal waters have been in continuous progress.

Sewage Purification at Bradford, England.—Six acres of the completed thirty acres of trickling filters at the Esholt disposal works in Bradford were put in operation October 2, 1929. The plant when completed will contain sixty acres of filters. The filters, which range in area from 3 to 11 acres, are built as watertight concrete tanks with level floors. The effluent channels in the floor are 48 ft. 9 in. apart and are covered with ordinary reinforced concrete flags. The uniform depth of the filters is six feet. Lump coal 1 by $^1/_2$ in. is used as the filter medium. Rectangular travelling distributors of the Hartley type are used. The sewage is siphoned from the feed troughs to cast-iron distributing tubes, which are fed with twenty-five $^{11}/_{32}$-in. diameter nozzles impinging on circular spray plates. The distributors are balanced by $^5/_{16}$-in. diameter steel ropes, which are also used for haulage purposes, passing round an arrangement of grooved drums and pulley wheels. The load on the distributors may vary from a minimum of 328,000 gallons per acre per day to a maximum of 919,600 gallons per acre per day.—*The Surveyor*, **76**, 327–328, October 11, 1929.

Sewage Treatment in Texas

By V. M. Ehlers[1]

It is easy to trace the progress of sewage disposal in the treatment processes that have been used in Texas, for the changes have largely taken place within the last fifteen years, since the writer became associated with the Texas State Department of Health. Prior to 1913, the year in which the Texas anti-stream-pollution law was passed, there were only about thirty sewer systems in the state serving the larger cities, and in only about a dozen of these cities was there any degree of sewage treatment. The usual procedure was to settle out the solids in septic tanks and turn the resulting effluent into any convenient stream or ravine. The population of Texas has increased since that time by more than a million and a half and the greater increase has been in urban centers. The public opinion which demanded the law of 1913 to protect the streams from unrestricted discharge of sewage has been well borne out by time. Today all major streams in the state are in good condition, except the Trinity River, which was virtually a sewer for Dallas and Fort Worth as far back as 1913.

The demand for a law which would reduce the possibility of further contamination of the streams was based more on a desire to correct the appearance of the streams than to protect drinking water supplies, oyster beds or irrigation water. Only about forty towns in Texas at the present time derive their water supplies from rivers, while the remaining three hundred or more are supplied by wells, reservoirs or springs. Our sewage disposal problems have therefore been more closely tied in with protection of fish life than protection of human life. This has brought about close coöperation between the State Health Department and the Game, Fish and Oyster Commission and has insured for our program the support of the sportsmen's organizations. So keen is the interest in fish life today that stream protection is one of the major activities of the Game, Fish and Oyster Commission.

Factors Influencing Sewage Treatment Methods

Temperature, rainfall, topography and stream flow vary so widely in Texas with the seasons and in the widely separated sections of the state that sewage disposal methods must necessarily vary. We have employed every device from fine screens to broad irrigation.

The average annual rainfall for extreme east Texas is 41 inches, while in the extreme western part of the state it is only 12 inches. The maximum recorded discharge of the Trinity River at Dallas is 140,000 cubic

[1] *Chief Sanitary Engineer, State Department of Health, Austin, Texas.*

feet per second (during a flood period) while the minimum is 6.8 cubic feet per second. This stream is somewhat typical of Texas rivers. It is obvious that during periods of drought, lack of dilution water makes it necessary to provide at least secondary treatment for all sewage intended for final discharge into a waterway in order to avoid a nuisance.

In the Rio Grande Valley a frost is a rarity but in the Panhandle the mercury frequently drops several degrees below zero. There are a number of localities where the thermometer registers well above 100° F. during the summer, and in such localities, if the dilution water available in streams is high in sulphates, odors are sure to result from the discharge of sewage therein. Hydrogen sulphide gas forms even in the sewer mains in some instances during hot weather, and as a result highly septic sewage is received at the treatment plant.

Sewer System Construction and Sewage Treatment Keep Pace

The anti-stream-pollution law furnished a legal basis for requiring the construction of sewage treatment plants, and the duty of supervising the work was given to the State Department of Health. Thus it became necessary to organize the Bureau of Sanitary Engineering, which came into being in 1915, with the writer as Director. Today there are 333 sewer systems in cities and 26 serving private and state institutions. Of the 333 municipal sewer systems, 322 have provided some form of treatment. In other words, all except 11 sewer systems have treatment plants. Of these 11, seven discharge into tide water, one practises lagooning and three discharge into rivers. All sewer systems are of the separate type except that of Wharton, Texas. Vitrified clay pipe is used in all but approximately 20 systems, which are constructed of concrete pipe.

There are 299 municipally owned sewer systems and 34 franchise systems, one owned by the state serving a college and the college town, and five county owned systems with small septic tank treatment plants. The municipal treatment plants include 227 Imhoff tanks, 143 sprinkling filters, 7 sand filters, 7 separate sedimentation and sludge digestion tanks, one fine screen (at Corpus Christi), 15 activated sludge plants, 30 cities using land disposal and 10 or more which have provided chlorination of the final effluent. Of the 15 activated sludge plants, 9 remove some of the suspended matter by preliminary settling tanks. One plant employs aeration to increase the rate on the filters, and contact aerators have been installed in one other plant.

There are no sanitary sewer districts in Texas, although their creation in the future is now made legal by an amendment passed by the last legislature providing for improvement districts in water control as well as the formation of sanitary sewer districts.

Comparative Popularity of Various Treatment Units[2]

Grit Chambers.—The first treatment plants constructed in Texas were provided with grit chambers, but they are no longer included, since all systems are of the separate type.

Oil Traps.—Oil skimming is employed rather advantageously at several plants.

Fine Screens.—North screens are employed at the packinghouse plant at Fort Worth and Dorr screens function at Corpus Christi.

Imhoff Tanks.—As a settling tank, the popularity of the Imhoff tank continues, although seven separate sedimentation and sludge digestion plants have been built. In recent years the Imhoff tanks are being equipped with apparatus for the withdrawal of the scum from the gas vents, and some plants have even been remodeled to provide for the removal of scum from the settling compartment. The first Imhoff tanks constructed, in many cases, did not provide sufficient sludge capacity. We are now requiring two cubic feet per capita, even in this warm climate. On the other hand, the flowing-through compartment is being decreased in size so as to provide a detention of only an hour and a half. In some instances this has been cut to one hour.

At eleven plants the gas vents of the Imhoff tanks have been closed and the gases trapped and burned. Scum breakers are provided where the gas vents are closed.

Separate Sedimentation and Sludge Digestion.—Only seven installations of this type have been tried out in Texas and as yet they have not proved satisfactory, which may be due to several causes. It has been demonstrated that stirring sludge is beneficial in hastening digestion, and the stirring is accomplished by rotating rakes or by air-driven sludge pumps. The separation of the solids from the liquid by mechanical means has proved satisfactory but the expense of the mechanical equipment is practically prohibitive for the smaller towns. Gravity removal of the solids has not given as good results. The reason for this has not been fully determined but is probably due to lack of operating attention. Full-time operators are not always provided and in many cases it is a financial impossibility to provide a man who can give his whole time to operating the sewage treatment plant.

Sand Filters.—Sand filters are used at a few plants where an exceptionally good effluent is desirable, but the cost of fine sand filtration is prohibitive for the smaller towns.

Sprinkling Filters.—This type of filter predominates in Texas. Most of the sprinkling filters are constructed of crushed rock varying in size

[2] A tabulation showing the number and types of sewage treatment plants in Texas as recorded with the Texas State Department of Health is given in the *Proceedings of the Eleventh Texas Water Works Short School*, published in 1929.

from $^3/_4$ to 2 inches and laid six feet deep. The settled sewage is applied to the filters at the rate of approximately one and a half million gallons per acre per day. Gravel is occasionally employed as filter material but is not as satisfactory as crushed rock.

Final Settling Tanks.—At a number of plants final settling tanks are provided to follow filters. Difficulties have been encountered in keeping the liquor in these tanks from becoming septic. Only in certain instances do we believe that the cost of final settling tanks is justifiable.

Activated Sludge.—The first activated sludge plant built in Texas was at San Marcos in 1916 and this plant is still functioning efficiently. The disposal of activated sludge on land has been found satisfactory. Under-excessive loads activated sludge plants fail. At the Houston plant

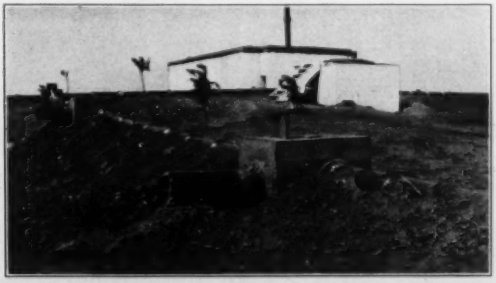


FIG. 1.—Sewage Farm, Munday, Texas. Settling Tank.

the manufacture of fertilizer from the sludge was proceeding satisfactorily when the building burned.

Air agitation has thus far proved more satisfactory than aeration by mechanical means. We predict that activated sludge treatment with short periods of aeration will supplement other types of biological treatment in this state in the future.

Land Disposal.—Cheap sandy land abounds in certain sections of Texas and in the arid regions provides a favorable medium for the disposal of settled effluent. When the top soil is kept loosened by plowing, and rotation is practised, one acre of land will care for 10,000 gallons of settled sewage per day (Figures 1 and 2).

Sludge Beds.—The conventional drying bed prevails in Texas. At first a great many plants were not provided with sufficient area and the present tendency is to allow one-half square foot per capita. At Dallas, Texas, the sludge is lagooned, and so far as complaints are concerned,

this method is giving satisfaction. In east Texas where there is excessive rainfall, some sludge drying beds have been glassed over so that drying may be carried on under all climatic conditions.

Location of Plants.—To a certain extent the location of a treatment plant depends upon the kind of treatment. For instance, covering or housing the Imhoff tank will reduce odors, and so will pre-chlorination. Usually cities locate their treatment plants well away from residences, but four cities in Texas have seen fit to abandon their old plants and construct new ones farther removed from the residential section rather than run the risk of complaints and law suits or resorting to expensive treatment.

Industrial Waste.—The disposal of industrial waste in Texas has not

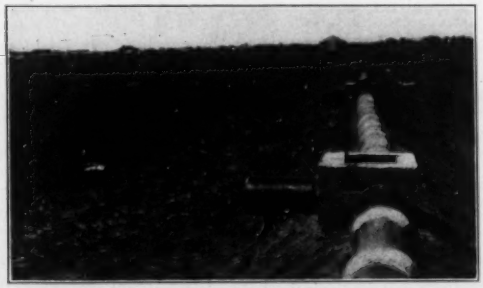


FIG. 2.—Sewage Farm, Munday, Texas. Distribution System.

become an acute problem except in the larger cities and in the oil centers. The most common industrial wastes are those discharged from packing houses, oil refineries and creameries or milk plants. In some instances wastes are given pre-treatment before being discharged into the sanitary sewer systems.

Plant Operation.—At only 46 plants are full-time operators employed. In 88 towns a daily visit is made to the plant, while in the majority of cases scant attention is given the treatment plants, visits being made at intervals of a week, a month or even a year. The importance of giving daily attention to plant operation is being taught in Texas through the annual short schools and through personal contact at the time of inspections by representatives of the State Department of Health.

Laboratories are maintained at only five plants and these in the larger cities.

Service Charges.—About 50 per cent of our towns require service

charges but the practice is confined to the smaller towns which need this means of deriving revenue. In such instances it has proved quite feasible and satisfactory.

Research and Schools.—A sewage research station has been established recently at Texas A. & M. College while annual schools of three or four days' duration are conducted for sewage plant operators.

Personal Experience with Sewage Works during Twenty-Three Years.—A review of India's various projects for purifying sewage is discussed in a paper by F. C. Temple.

The first installation was in the Elan Valley, consisting of a sedimentation box and a trough full of charcoal for a filter. In 1904, at Fort William, Calcutta, a water-flushed latrine was installed which discharged into a so-called septic tank. The effluent ran through automatic tipping troughs onto enclosed cinder filters. At Muzaffarpur in 1906, two septic tanks and a contact bed were installed but, since dilution water had to be hand-pumped, the tanks were finally abandoned. At Entally, Calcutta, a sewage experiment station was built under the direction of Col. W. W. Clemesha. Various types of septic tanks and filter distributors were tried out.

For the Reserve Police Lines at Bankipur Patna a septic tank latrine and percolating filter were installed. At the Patna General Hospital in 1912 a septic tank with three rectangular chambers was built. The first chamber was divided by a hanging baffle and all chambers were fitted with diaphragms of Travis design. Percolating filters followed the septic tank treatment.

At the Patna Government House and High Court an underground sewerage system was installed. Septic tanks preceded filters, which were of brick ballast in graded layers. Effluent was disposed of on land. The new Patna sewerage system consists of five different types of septic tanks—"A" is a two-storied tank somewhat like the Travis hydrolytic tank, "B" and "C" are modified Imhoff tanks, "D" and "E" are simple Clemesha tanks, "E" having also a macerating tank. Brushwood filters are used.

At Jamshedpur, septic tanks were first used but now an activated sludge plant is installed and designed to treat a population of 3000 at 38 gallons per head and a Simplex plant designed to treat 40,000 gallons per day. The two activated sludge processes are being compared. The sludge is used successfully as fertilizer.—*Proc. Assn. Managers of Sewage Disposal Works* (England), pp. 75–95, 1928.

Bay Disposal and Chlorination at Newport Beach, California[1]

BY RICHARD L. PATTERSON[2]

The City of Newport Beach is almost entirely a residential city and summer resort, located on Newport Bay. Its permanent population is 4500, but during the four summer months the population increases to about 10,000, and to about 20,000 on week-ends and holidays. About 60 per cent of the area within the city is sewered. The present sewer system is divided into two separate systems. One system provides for Balboa Island and the other provides for the sand spit about three miles long which lies between the bay and the ocean.

The system along the sand spit will be discussed in this article. This sewer system includes about 11.0 miles of cement pipe ranging from 8 to 20 inches in diameter. The topography is such that very flat grades are necessary. The entire sewered area with a length of about 3 miles and a width of 700 feet to one-half mile has an elevation ranging up from 7 to 12 feet above mean lower low water. The sewage is lifted at three different points by means of pumps. The first pumping station is located at the Imhoff tank, the second is 7400 feet from Station 1 and the third is 6400 feet from Station 2.

The Imhoff tank and Station 1 are adjacent to each other at the side of the state highway 600 feet west of the Newport Beach-Santa Ana Road. This location was selected primarily to avoid contamination of ocean water anywhere along the three miles of beach front. This beach is used extensively for bathing. This site at the time of construction in 1922 was remarkably well isolated, being cut off from the city by the Santa Ana River and 1000 feet of marsh land, and cut off from the only public road in the vicinity by a high railroad embankment. There was not a dwelling within 1000 feet. With the growth of the city, the dredging of the bay and the construction of the state highway along side of the Imhoff tank, its location is very undesirable. The tank is heavily overloaded, the retention time in the flowing through chamber being only 45 minutes during the peak flow.

The effluent from the Imhoff tank is discharged into the former channel of the Santa Ana River where the channel widens out into Newport Bay. Shortly after construction of the Imhoff tank, the Santa Ana River was cut off from entering Newport Bay and a new outlet constructed to the ocean. The two high tides each day provide a large quantity of diluting water with which the sewage mixes. The range of the tide is 5.1 feet.

[1] *Read at Second Annual Meeting, California Sewage Works Association, Oakland, October 9, 1929.*

[2] *City Engineer, Newport Beach, California.*

The amount of sewage treated by this plant is about 400,000 gallons daily during the winter time and 780,000 gallons daily during the summer months. Owing to the low velocities and the intermitting operation of the pumps, the sewage reaches the Imhoff tank in a more or less stale condition, giving rise to very objectionable odors.

Chlorination for Odor Control.—There was imperative need of relief from the odors from the Imhoff tank, as numerous complaints had been made by property owners in the vicinity of the plant and from motorists passing along the state highway. Mr. R. F. Goudey of the California State Department of Public Health, suggested that chlorination be tried. Mr. Goudey was carrying on experimental work on chlorination for odor control on the Orange County-Santa Ana outfall sewer. The city, in coöperation with Mr. L. G. Sovulewski of the Wallace and Tiernan Company, carried on experimental work from July 12, 1928, to September, 1928. Because of the encouraging results obtained the city on September 28, 1928, purchased a Wallace and Tiernan chlorinator which is now in use for controlling the dose of chlorine applied to the sewage.

Field Experiments.—Before chlorination was started samples of the sewage were taken at various points and the average amount of hydrogen sulphide was determined, with results as follows:

	Average Hydrogen Sulphide, P. p. m.
M. H. 1 block above Station 3	1.7
Station 3	3.4
Station 2	4.0
Easterly of Station 1	7.5
Manhole 300 feet above Pump Sump, Station 1	9.5
Equalizing Basin	6.5
Effluent, Imhoff tank	7.9

These results show that starting at the upper manhole, there was a gradual increase in the amount of hydrogen sulphide up to the effluent from the treatment plant. Attention is called to the decrease in the amount of hydrogen sulphide in the equalizing basin. This was due to the liberation of the gases by a three foot drop from the end of the discharge pipe.

A chlorinator was installed at Station 2, as the experiments on the Santa Ana Outfall Sewer indicated that the chlorine demand would be decreased by destroying the sulphate-splitting organisms before hydrogen sulphide could be produced in large quantities. The following tests were made, using a dosage of 45 and 100 lb. of chlorine per 24 hours.

The estimated flow at this point was 450,000 gallons per 24 hours. Using a chlorine dosage of 45 lb. per 24 hours, which was equivalent to 13.2 p. p. m., the hydrogen sulphide was reduced from an average of 6.5 p. p. m. to 4.6 p. p. m. in the equalizing basin. Using a chlorine dosage

Date	Chlorine Dose, Pounds per 24 Hours	Time of Run	Hydrogen Sulphide		
			Pump Sta. 2, Un-chlorinated	P. p. m. M. H. 300 Ft. above Sta. 1	P. p. m. Equalizing Basin
Aug. 2	45	24 hr.	4.4	4.6	3.7
Aug. 5	45	4 days	4.0	5.7	4.6
Aug. 23	100	24 hr.	3.9	3.6	2.7
Aug. 24	100	36 hr.	4.0	4.2	2.8

of 100 lb. per 24 hours, which was equivalent to 30 p. p. m. the hydrogen sulphide was reduced to 2.8 p. p. m. in the equalizing basin.

The odors at the Imhoff tank were reduced but not sufficiently to prevent complaint. It was then decided to move the chlorinator to the Imhoff tank, which was done September 1, 1928. The chlorine was mixed with the sewage in the pump pit. After experimenting with various rates of chlorine dosages and varying the time of application, it was found that by using a dosage of 70 lb. per 24 hours, which was equivalent to 11.7 p. p. m. from 11 a.m. to midnight, the hydrogen sulphide in the equalizing basin was reduced to 1 p. p. m. and less, and in the effluent from the tank to 2.0 p. p. m. By keeping the hydrogen sulphide content down to 1.5 p. p. m. or lower odors were noticeably controlled at the Imhoff tank and at the effluent discharge pipe. The tank effluent at no time contained any residual chlorine. Prior to chlorination the odors from the tank between midnight and noon were not sufficient to cause complaint, so it was considered unnecessary to chlorinate during this period. The chlorination at the rate of 70 lb. per 24 hours was carried on for ten (10) days. The odor nuisance was considerably improved.

Results of Pre-Chlorination.—The Enslow method was employed for determinations of hydrogen sulphide. This method gave consistent results. The reduction of hydrogen sulphide, however, is not the best way to judge results. A more practical criterion is by the number of complaints. Residents in the vicinity of the Imhoff Tank stated that the odors were noticeable only on a few occasions since the chlorination experiments were started, and that conditions were greatly improved over the previous summer. A chlorine dose of from 10 p. p. m. to 12 p. p. m. has proved to be sufficient to control the odors.

The chlorine demand was reduced considerably by certain improvements in the Imhoff tank. The sewage from the pump sump was discharged over the top of the walls of the equalizing basin and permitted to drop about three feet into the basin. This agitation aided in liberating the gases. The effluent pipe was changed so that the effluent discharged on the floor of the basin. A baffle gate built of 1 × 4 in. strips, one inch apart, cut to the shape of the walls, was placed in each flowing-through chamber to distribute the flow more uniformly. The effluent passed over a weir and dropped two feet into a trough leading to the outlet pipe. This drop aided in liberating the gases. The drop was reduced to four inches.

Along with better care of operation of the Imhoff tank these changes helped to reduce the chlorine demand.

The amount of chlorine used during the winter months average 20 lb. per day and during the summer months 35 lb. per day. When the wind is from the southeast, the chlorination is discontinued, as the land to the northwest of the plant is undeveloped.

The pre-chlorination of sewage for odor control at Newport Beach has been in use for one year with satisfactory results when consideration is given the small quantity of chlorine applied. The pre-chlorination of the sewage has in no way adversely affected the function of the tank. If anything, pre-chlorination has improved operation of the tank.

Cost Data for Chlorination

The capital outlay is as follows:

Chlorinator and appliances	$1525.00
Building	75.00
Total	$1600.00

Cost of Operation

For one year

Chlorine, 8050 lbs. at 6½c. (Average cost per day $1.54)	$ 523.25
Water for operation of chlorinator	75.00
Interest and depreciation on equipment (15% of $1600.00)	240.00
Total	$ 838.25

Cost per day = $2.30.

Bay Disposal.—The Imhoff tank hereinbefore referred to was completed in 1922, and the Imhoff tank which serves Balboa Island was completed in 1926. The discharge from both tanks empties into Newport Bay. The two high tides each day provide large quantities of diluting water with which the effluent mixes. The effluent from the tanks is not treated in any manner at present, but it is planned to use chlorination during the summer of 1930.

The discharge of the effluent into the bay has proved very satisfactory. Samples of the water in the bay taken during the summer months show that the condition of the water is very satisfactory for bathing except for a distance of about 600 feet from the discharge pipe from Tank 1 where the channel is narrow and shallow, and does not allow sufficient mixing of the effluent with the bay water.

With the development of the district in the vicinity of the first Imhoff tank and the increased use of the bay for bathing, it will soon be necessary to provide better treatment of the sewage. The present plans are to abandon the tank and to construct a new disposal plant alongside of the Santa Ana River outlet to the Pacific Ocean at the westerly city limits.

Fly Control at Sewage Treatment Plants*

BY W. B. HERMS**

Flies of many species are attracted to sewage from far and wide partly because of food, but particularly because of the excellent pabulum it furnishes for the development of fly larvae. Under favorable temperature conditions semi-solid sewage will probably produce a maximum number of flies, provided it remains long enough in a relatively undisturbed condition. The more liquid the sewage the less likely is it to support the more dangerous house invading species, that is, flies which might contaminate food, such as the housefly and blowfly. Fly larvae are subject to drowning in liquid, but this does not apply so forcibly to the rat-tailed larvae referred to later.

No doubt the desire to control flies at sewage treatment plants is based on a two-fold menace, namely, danger from contamination by pathogenic organisms of fecal origin, and danger of wholesale fly production. The first menace would appear to be greatest where the raw sewage is exposed directly to flies. This, it would seem to me, could be largely obviated by adequate screening. The screened structure should be high enough over the plant to admit the sewage works operators. Certainly the exposure of raw sewage to flies ought not to be tolerated, particularly when treatment plants are not far removed from human habitations, dairies and slaughter houses. The distance that flies travel has been the object of experimentation by a number of investigators, namely, Bishopp and Laake,[1] who found that *Musca domestica* spread a maximum distance of 13.14 miles from the point of release, and that marked specimens had traveled a distance of over six miles in less than twenty-four hours. Flies have a tendency to spread with the wind, though they are known to travel at right angles to and against it. The above authors conclude that "the influence of moderate winds on dissemination is not of great importance." They also concluded that the passing of vehicles along highways was not a dominant factor in dispersion.

Principal Species Concerned

Among the commoner species of flies breeding in sewage are the following: *Musca domestica*, the common housefly; *Calliphora erythrocephala* and *C. vomitoria*, blue bottle flies; *Lucilia sericata* and *L. caesar*, green bottle flies; *Fannia scalaris* and *F. canicularis*, latrine flies; *Sarcophaga haemorrhoidalis* and other species of *Sarcophaga*, commonly known as flesh flies or carrion flies; *Eristalis tenax* and other species of *Eristalis*, drone flies, so-called because of their resemblance to drone bees; and *Muscina stabulans*.

* *Presented at Second Annual Meeting, California Sewage Works Association, Oakland, October 8, 1929.*

** *Professor of Parasitology, Univ. of California, Berkeley.*

Of the above named species only two or three are really house-invading. In a report by Howard[2] on species of flies found in various parts of the United States, it was stated that nearly 95 per cent were *Musca domestica;* others, notably Kobayashi[3] of Japan and Korea, have reported about 90 per cent. The remaining 5 to 10 per cent consist mainly of *Calliphora spp.* (blue bottle flies) and a few others. The green bottle flies, *Lucilia spp.*, are typically out-of-door species, although they do find their way indoors now and then. The latrine fly and lesser housefly, *Fannia spp.*, are commonly found indoors and have the habit of circling and swinging back and forth almost ceaselessly in the middle of the room near the ceiling. They seldom, if ever, alight on food. The drone flies (adults of the rat-tailed larvae), *Eristalis spp.*, are flower flies never found indoors except by accident. So far as health or even comfort is concerned, really no attention need be given the latter.

Trapping Flies

Fly traps are no doubt of some importance in mitigating the fly nuisance at sewage treatment plants. Traps should be as simple as possible and can be readily made or purchased. It must be borne in mind that a fly trap must be provided with bait. The sense of smell plays a most important rôle in the life of the fly, hence suitable substances must be used as bait. As bait for houseflies, Bishopp[4] recommends the use of a mixture of cheap molasses ("blackstrap") one part, and water three parts. For blow flies he recommends "gut slime" which may be obtained from meat packing houses where sausage casings are prepared.

If repellents are desired, the use of creosote oil is suggested. Painting beams and other surfaces where flies are inclined to congregate has given good results.

Control of Fly Larvae

A knowledge of life history and the effects of varying environmental conditions, such as temperature and moisture, are fundamental to successful control operations.

Much of the fly breeding in connection with sewage works occurs in the sludge beds at the end of the treatment process. In dealing with this problem the fact must not be overlooked that the full grown larvae have a strong tendency to migrate (Hutchison[5]) to drier situations which may take them outside of the sludge bed area. Even immature larvae will leave the pabulum when it becomes dry.

This migratory habit of immature larvae indicates a method of control which is probably impractical in the present connection, but it is well to bear in mind that when even the most favorable pabulum is spread out thin, to permit of rapid desiccation, it is quite unfavorable for fly breeding.

Sprinkling the infested sludge with a liquid containing chemicals lethal to the larvae would appear to be a reasonable procedure. For the destruction of fly larvae in human excrement the use of sodium cyanide, one ounce to a gallon of water, has given good results in Nanking, China, as reported to me by my colleague, Prof. C. W. Woodworth. This solution was simply applied to the excreta by means of a hand-sprinkling can. Whether a similar method could be applied to maggot infested sludge remains to be seen.

The representative of one of our leading oil companies has informed me that an oil will soon be on the market for the purpose of controlling fly larvae in manure or other breeding materials. This should be tried out on sludge as well as borax, now known to be a good larvacide. In any case cost of material, length of time it remains effective, and ease of application, in addition to its larvicidal effect, must be taken into consideration. In general, however, I would suggest that the use of chemicals be avoided and that the more natural means of control be employed.

Discussion

Mr. R. F. Goudey reported that during the spring and summer of 1925 there was a big epidemic of flies at the Pasadena sewage treatment plant. The breeding of flies was occurring in 101 sludge beds containing 2 to 4 ft. depth of activated sludge and covering about 10 acres. The second source of fly breeding was in a 40-acre orange grove where filtered sludge, about 85 per cent moisture, was being disposed of on the surface of the ground by partially plowing under for fertilizer. Subsequent applications brought old material to the surface and aggravated fly breeding.

The breeding of flies due to these two conditions caused extreme nuisance to people living 500 to 1000 ft. from the plant. In the buildings around the plant, flies literally covered inside and outside walls. Never before or afterward have I seen such heavily infested areas of flies.

The steps taken to remedy this situation proved very effective. They included, first, deep plowing of the orchard and discontinuance of further applications of wet sludge; second, an attack was directed against the sludge beds by sprinkling 1 lb. of calcined colemanite (crude calcium borate) on every 10 cu. ft. of sludge, and then pouring 2 or 3 gal. of water over the surface. This method did not prove effective because the sludge continually cracked and exposed new surfaces. The borate cost $5.15 per 100 pounds. It likewise was not practical to spray with oil because the crust which formed at the surface would not allow the oil to penetrate, and likewise new areas were being constantly exposed to the surface.

The practical solution which was worked out was to dig trenches and move all of the lagooned sludge into pits. These pits were then given a top coating of asphalt and gravel, exactly as one would construct an asphalt

road. This hard surface prevented flies gaining access to the sludge and likewise prevented maggots from crawling out. The cost of burying all of this sludge was $4500, and the time required was about two months. Fly breeding was effectively stopped.

Gypsum was tried as a method of fly control, but was not effective. It facilitated in de-watering sludge to the extent that flies could not breed in it.

Professor Herms added that the modern sewage treatment plants do not have a very big fly problem, and that at the Santa Cruz plant, for example, he saw less flies than he has seen at some modern bakeries and other manufacturing concerns. Mr. Goudey agreed with Prof. Herms that chemicals should not be used but that the conditions that breed flies should be found and controlled.

Mr. Rawn reported a serious fly problem at the Los Angeles County Sanitation District plant where raw sludge is run on to beds. Last year a small brown fly and a very small black fly bred, and this year the housefly is breeding. Between midnight and seven o'clock each morning countless millions were burned, but the housefly cannot be reached by burning. Operation of three unused tanks as digestion tanks and the discharge of digested sludge, which dries more quickly, has checked the trouble. Mr. Rawn's advice is not to expect raw sludge to dry on beds without a fly nuisance. A blow torch on top of the sludge raises the temperature one inch below only four degrees, due to almost perfect insulation, so it is almost impossible to burn the larvae.

Mr. Rantsma said he thought Fresno had as bad a fly nuisance as any. Experiences there coincide with those at other plants in that chemicals have not been effective, and he considers their use a waste of time. Traps about 18 inches by 2 feet high are now used with black strap molasses. Chemicals are used on the flies caught, and then they are burned so that they will not come back to life again. The flies breed on the surface of open tanks. Formerly when tanks were covered, there were no flies, even though they were not screened. However, the tanks could not be cleaned so the covers were removed and since then there has been no fly trouble. Screening at a cost of $12,000 to $15,000 would control flies but at present no funds are available.

Mr. Foreman told of an experience at Tulare where larvae grew very thickly but only a few pupated, probably due to rapid drying of sludge.

Mr. Batty reported trouble with fly breeding in screenings at Hyperion, regardless of the depth of cover. Spraying with $1\frac{1}{2}$ pounds of pure carbolic acid and 40 pounds of caustic soda in 60 gallons of water has controlled them.

Mr. Gray confirmed statements of other speakers and said he felt the necessary solution was quick drying of sludge.

Prof. Herms, replying to a question, said that quick drying was more

important than temperature in controlling flies. He said he had heard of instances when beams of light entered a septic tank through a knot hole in the roof, which also allowed flies to enter, and as a result a vast number of eggs were deposited in the vicinity of the hole. This indicates that tanks must be completely covered and completely darkened. He described the life cycle of *Musca domestica* as varying with the temperature. With increasing temperatures the length of time of each stage is lessened. In fall and summer the fly remains in the egg stage from 8 to 24 hours, then it hatches into a larva. If food is ample the larval period is usually four days, then the larva migrates, and in 24 to 36 hours it pupates. The pupa stage is greatly affected by changes in temperature. In summer the pupal stage usually lasts 3 to 6 days when the fly emerges. Nine days is the very shortest period for the life cycle, and this time is lengthened by decreasing temperature.

References

[1] F. C. Bishopp and E. W. Laake, "Dispersion of Flies by Flight," *Jour. Agric. Res.*, Vol. XXI, No. 10, pp. 729–766, 1921.

[2] L. O. Howard, "A Contribution to the Study of the Insect Fauna of Human Excrement," *Proc. Wash. Acad. Sci.*, Vol. II, pp. 541–604, Dec. 28, 1900.

[3] Harujiro Kobayashi, "House Frequenting Flies and Their Seasonal Prevalence in Japan and Korea," *Mitteilungen der Medizinischen Fachschule zu Keijo* (*Separatabdruck*), 1918.

[4] F. C. Bishopp, "Flytraps and Their Operation," U. S. Dept. of Agr., *Farmers' Bull.*, **734**, 14 pp., 1925.

[5] R. H. Hutchison, "The Migratory Habit of Housefly Larvae as Indicating a Favorable Remedial Measure. An Account of Progress," U. S. Dept. of Agr., *Bureau of Entom., Bull.* **14** (professional paper), 11 pp., 1914.

Discussion by Frank L. Flood* of Paper, "Experiments on the Dewatering of Sewage Sludge with a Centrifuge," by C. E. Keefer and Herman Kratz. Sewage Works Journal, January, 1929

The experimental data of tests made at Baltimore during 1925 on the dewatering of sludge by centrifuge are a valuable contribution to engineering knowledge on the subject of sludge disposal, and the authors of the paper are to be commended for giving the results of the experiments in such detailed form.

Referring to the comparative study of the cost of dewatering sludge by centrifuge and on sludge drying beds, the authors compute the volume of dewatered sludge cake produced per year by the centrifuge plant as 25,910 cu. yd. This apparently is based on the reduction of 91,700 cu. yd. of sludge to be dewatered per year, from a moisture content of 91.82 per cent to a moisture content of 71 per cent after dewatering. However, about 35 per cent of the sludge solids pass off in the effluent of the centrifuge so that the dewatered cake would amount to only 65 per cent of 25,910 cu. yd. or 16,850 cu. yd. per year.

The estimated total cost of dewatering by centrifuge would then be $2.05 instead of $1.33 per cu. yd. of sludge cake, as compared with $1.30 per cu. yd. of dried sludge for air drying of sludge on sludge beds as estimated by the authors.

The average moisture of the sludge dewatered by the centrifuge during the endurance test, as given in Table VI, was 94.05 per cent, and the average quantity of cake produced, as given in Table VII, was 11,201 lb. during 6 hours, 45 minutes, or 1660 lb. per hour. The average moisture content of the sludge dewatered during the three days (March 9, March 30 and April 27), when the moisture content was the lowest recorded during the test run was 92.28 per cent and the average quantity of cake produced was 1537 lb. per hour. The average quantity of sludge dewatered during these three days was 1223 gal. per hour as compared with 1480 gal. per hour average quantity dewatered during the test run. It does not appear to be established by the experiments that the centrifuge will handle as large a quantity of sludge on the dry solids basis when the moisture content is low, say at 91 per cent, as at the average of 94 per cent during the test run. Moreover, the per cent removal of dry solids was less during the three runs with the sludge containing the highest percentage of solids, averaging 60.2 per cent as compared with 65.4 per cent average for all the runs during the endurance test.

From the data given in Tables VI and VII it is as reasonable to compute

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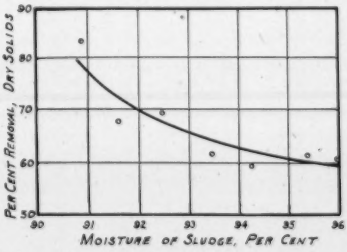
the capacity of the centrifuge on the basis of the cake produced as on the quantity of wet sludge handled. Assuming the centrifuge to have a capacity for producing 1660 lb. per hour of dewatered cake at 71.5 per cent moisture, the capacity of 5.22 units, operating 8 hours per day 300 days per year, would be about 20,900,000 lb. or approximately 12,400 cu. yd. per year. The cost per cubic yard of dewatered sludge by centrifuge would then be about $2.80, or more than twice the unit cost estimated by the authors for drying on underdrained sand beds.

It is evident that additional experimentation, to determine the efficiency of the centrifuge with sludge at the moisture content normally to be expected in the sludge as drawn from Imhoff or separate sludge digestion tanks, would be necessary before adoption of the centrifuge even for the removal of about 65 per cent of the sludge solid content, and, as the authors point out, there is still the problem of the disposal of the centrifuge effluent containing 2 to 4 per cent solids.

Reply by Mr. C. E. Keefer

With reference to Mr. Frank L. Flood's discussion of the paper prepared by Mr. Kratz and me, entitled "Experiments on the Dewatering of Sewage Sludge with a Centrifuge," I feel that the discussion as he has presented it should be published. His cost estimates on the dewatering of sludge are essentially correct. With reference to the fourth paragraph of his discussion, I have prepared a curve showing the relationship between the per cent removal of dry solids by this centrifuge and the moisture in the sludge which is being dewatered. You will note there is some increase in the per cent removal as the moisture becomes less. It is impossible to arrive at any conclusions regarding this from the tables given in the original article, as all results are averages of a number of individual determinations.



Although the comparative costs of dewatering sludge on sand beds and by a centrifuge are of interest when based on the quantity of dry material dewatered, the most desirable comparison is on the wet sludge before it is dried. The following table indicates that the costs are about the same, the cost of drying on sand beds being about 1 cent per cubic yard less.

ESTIMATED COST OF DEWATERING SLUDGE ON SAND BEDS AND BY CENTRIFUGE

On Sand Beds	
Quantity of wet sludge to dewater (91.8% moisture)	91,700 cu. yd.
Quantity of dry sludge	25,910 cu. yd.
Yearly cost	$33,683.00
Unit cost wet basis	0.367 per cu. yd.
Unit cost dry basis	1.30 per cu. yd.
By Centrifuge	
Quantity of wet sludge to dewater (91.8% moisture)	91,700 cu. yd.
Quantity of dry sludge	12,400 cu. yd.
Yearly cost	$34,545.00
Unit cost wet basis	0.377 per cu. yd.
Unit cost dry basis	2.79 per cu. yd.

Editor's Note: Mr. Flood, in reply, points out that only 65 per cent of the solids in the wet sludge were removed, therefore the effective volume of wet sludge treated by centrifuge should be 66,400 cu. yd. instead of 91,700 cubic yards.

If the capacity were reduced to 12,400 cu. yd. per year, Mr. Flood calculates that the effective volume of wet sludge should be only 43,100 cu. yd., equivalent to a cost of $0.801 per cu. yd., as compared with Mr. Keefer's estimate of $0.377 per cu. yd., wet basis.

It is apparent that the large amount of suspended solids in the effluent from the centrifuge is a serious barrier to the economic possibilities of this process.

Industrial Wastes and Stream Pollution

Treatment of Dairy Wastes*

By C. L. Walker**

Volume of Milk

The State of New York produced seven and one-sixth billion pounds of milk during the year 1927 (according to figures published by the New York State Department of Agriculture and Markets in Bulletin No. 214). This is equivalent to two and one-fourth million gallons daily throughout the year. Approximately 73 per cent of this milk was sold to milk factories or large milk dealers, the balance being sold to consumers, to small retailers, or used on the farm for feeding to calves, for the manufacture of butter, or as fluid milk. The milk produced in New York State constitutes about 6 per cent of all produced in the United States.

Estimated Volume of Waste Produced

The problem of disposal of dairy waste is not caused by the milk sold to consumers, or to small retailers, or that used on the farm, since this does not result in the production of any appreciable quantity of waste in any one locality. The problem of milk waste disposal centers rather around the milk factories, or the receiving stations of the large milk dealers. With an increasing tendency to manufacture in factories with machinery, and to form coöperative associations or to consolidate plants, the tendency also is to aggravate rather than to lessen the problem.

Of the 73 per cent of milk sold to milk factories or large milk dealers in 1927 about 40 per cent was sold as fluid milk and cream, 3.3 per cent as sweetened or unsweetened condensed and evaporated milk, 3.3 per cent as ice cream mix, 0.6 per cent as milk sugar, and 1.5 per cent as butter and cheese. On the assumptions that about 3 gallons of waste are produced for every pound of cheese and for every pound of butter manufactured, and that 3 gallons of waste are produced in handling 10 gallons of fluid milk, the average total volume of milk waste produced daily in New York State is not far from 1,000,000 gallons. The seasonal character of the industry, however, brings the average flow for the months of May, June, July and August up to about 3,000,000 gallons daily, or nearly 5 cubic feet per second. If the average working day is assumed to be of twelve hours

* *Presented at the Fall Meeting of the New York State Sewage Works Association, Schenectady, Oct. 19, 1929.*

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duration the average hourly flow for four months of the year would be 10 cubic feet per second, and the maximum hourly rate much greater.

Character of the Waste

With the exception of the waste from the manufacture of butter and of cheese, the discharge from factories normally consists of less than 1 per cent of the product, plus the wash water used in the process. The waste from butter and cheese factories is strong and the volume of buttermilk and of whey discharged from the plant is large, but the volume of wash water per pound of milk handled is small.

If the waste from a receiving station contains 0.5 per cent of the milk received—less than one-half pint per 10-gallon can of milk handled—and the volume of wash water is equal to 3 gallons per 10-gallon can, the resulting waste would contain over 850 p. p. m. of lactose sugar capable of producing an acid reaction in the waste through fermentation to lactic acid; over 600 p. p. m. of butter, capable of mechanically clogging filtering units, or of producing varying amounts of the nine fatty acids found in butter, two of which are soluble, and four volatile; and about 25 p. p. m. of organic nitrogen.

If the waste from a cheese factory contains the whey produced and two volumes of wash water for each volume of whey, the resulting waste would contain about 5000 p. p. m. of casein and albumen, about 1600 p. p. m. of lactose sugar, and about 250 p. p. m. of organic nitrogen. This latter waste would be over 10 times as strong as an average sewage on the basis of organic nitrogen content, and on the basis of total solids, but the total solids of the whey are mainly in solution.

Treatment of Weak Dairy Wastes

The wastes from receiving stations, and from butter and cheese factories where buttermilk and whey are excluded from the wastes, contain the spilled or wasted whole milk or cream; the wash water from cans, from the equipment used in handling the milk or manufacturing the butter or cheese, and from floor washings.

Extensive experiments have been made on wastes of this character and the results of the experiments have been published.

(*a*) In 1898 experiments were carried on at the Lawrence Experiment Station by the Massachusetts State Board of Health[1] using a 1 per cent solution of skimmed milk.

(*b*) In 1916 Mr. A. E. Kimberley[2] reported on the operation of a plant designed for the Sunbury Coöperative Creamery Company at Sunbury, Ohio.

(*c*) In 1920 the U. S. Public Health Service issued Bulletin 109, describing the experiments carried on during 1916 and 1917 in treating the waste from a factory at Grove City, Pennsylvania. "The factory manufactured butter, cottage cheese, casein, and condensed milk," but the "waste included only such liquids as resulted from wash-

ing apparatus, utensils, the floors, from laboratory operation including testing acids and waste from the toilet rooms and lavatories." This work was under the supervision of Mr. Harry Hommon.[3]

(*d*) In 1923 the Agricultural Experiment Station at Cornell University[4] published the results of experiments carried out during the years 1920–1921 under the supervision of a committee of the Faculty of the College of Agriculture, consisting of Professors Cavanaugh, as Chairman, Needham, Stocking and Riley. The wastes used in this work were either artificially prepared mixtures, or the wash water waste originating in the bottling room of the Dairy Department, Cornell University.

(*e*) In August, 1923, the Iowa State College of Agriculture and Mechanic Arts[5] published *Bulletin* 68, containing the results of "Aeration Studies on Creamery Waste Purification," using a 2 per cent skimmed milk solution.

(*f*) In September, 1926, *Bulletin* 81 was issued by the Iowa State College of Agriculture and Mechanic Arts,[6] describing the tests made to determine "The Purification of Skim-Milk Solutions on a Lath Filter." Solutions of skimmed milk in concentrations of 0.5, 1.0 and 1.5 per cent were used in these tests. The work described in *Bulletin* 68 was carried out by Levine, Burke and Soppeland; in *Bulletin* 81, by Levine, Burke and Linton.

(*g*) The April 10, 1929, issue of the *Butter and Cheese Journal* contained an article prepared by members of the Wisconsin State Board of Health,[7] entitled "Progress in Dairy Waste Treatment in Wisconsin." This article by Warrick, Homewood and Ruf describes the performance of an experimental plant at DeForest, Wisconsin. The waste included wash water from cheese vats, milk cans, utensils and the floor wash.

These and other experiments in general indicated that such wastes can be successfully treated without excessive cost by using certain units now employed in treating municipal sewage.

The work of the United States Public Health Service by Hommon and that of the Committee of the College of Agriculture of Cornell University led to a recommendation against the use of Imhoff tanks, because the butter and protein persistently arose to the surface of the tank and the solids adsorbed by this scum caused the clogging of filter units or rendered the Imhoff tank, in reality, only a septic tank.

The results of the same two investigations suggested the use of septic tanks having a detention period of not less than 24 hours nor more than 72 hours.

Sand filters preceded by septic tanks, according to the same investigations, operated at rates varying from 50,000 to 75,000 gallons per acre per day, regularly gave alkaline effluents and reduced the organic nitrogen content 80 to 98 per cent, and the oxygen consumed 45 to 95 per cent.

The work carried out by the Committee at Cornell University and by the Wisconsin State Board of Health showed that sprinkling or percolating filters of one-inch material could be operated at rates ranging from 500,000 to 2,000,000 gallons per acre per day for depths of bed ranging from 3.5 to 6 feet. The work at Cornell University showed that reductions of organic nitrogen and of oxygen consumed, with 3.5 ft. depth, amounted to 65 per cent. The work in Wisconsin showed that the degree of purification increased with

depth of filter and led to a recommended depth of 8 ft. for such filters. The work with lath filters by the Cornell Committee and at Iowa State College indicated that such filters could be operated at rates ranging from 250,000 to 2,250,000 gallons per acre per day, and that the organic nitrogen content of the applied waste could be reduced from 65 per cent upward, depending upon the depth of the filter.

The activated sludge process was found impracticable and generally unsatisfactory by the workers at Cornell, at Iowa State College and in Wisconsin.

Chemical treatment, while effective for such wastes, calls for much more careful supervision than is necessary with the above mentioned units, and is also expensive. Chemical treatment studies were still being conducted in 1929 by the Wisconsin State Board of Health[7] "along with an investigation of the special application of chlorine in retarding bacterial decomposition of dairy wastes."

Summing up the experiments with weak dairy wastes, the results indicate that aerobic rather than anaerobic units are most effective, though the activated sludge method was not found satisfactory or practicable for the small volume of waste developed at the average plant. The experiments also showed that these wastes can be applied to porous aerobic beds at rates not differing materially from those used in treating municipal sewage.

Neither an Imhoff nor a septic tank was used in the 1928 work with trickling filters at DeForest, Wisconsin. The waste was collected in a receiving tank (a converted septic tank) operated as a flow-equalizing unit to give uniform feed to the filters.

At the present time four treatment plants are in operation, at Blufton, Holgate, East Liverpool and Sunbury, Ohio. These plants are under the supervision of Mr. A. E. Kimberley, as consulting engineer, who has been retained by the committee of the milk industry to carry on research. In a letter written about a month ago, Mr. Waring, Chief Engineer of the State Board of Health of Ohio, in speaking of these plants stated, "In operating the treatment works the waste water from the plant is conducted directly to the trickling filter without prior treatment. Storage tanks of sufficient capacity to provide for an equalization of flow have been provided ahead of the filters in each case. The filter effluent is discharged directly to the receiving stream without further treatment."

"The data which we have gathered are very interesting, and we believe that our coming report on the work done will be of much value to the milk industry."

Treatment of Concentrated Dairy Wastes

The concentrated wastes most commonly produced in the industry are buttermilk, whey from cheese and casein factories, milk or milk products

accidentally spilled upon the floor of the factory, and occasionally wastage of skimmed milk or of milk products of an unsatisfactory quality. Little work of an experimental nature has been done with such wastes. Buttermilk is used for a beverage or other purposes and its disposal does not constitute so serious a problem as does the disposal of whey. Both recovery of products or utilization, and treatment of whey have been attempted and progress has been made, but more experimental work is needed.

Disposal of Whey

Hog Feeding.—Hog feeding and drying at present appear to be the two most feasible methods of utilizing whey. When used as a hog food, the whey must be pasteurized before leaving the factory and a separate set of cans must be used in transporting the whey to the farms. There are several reasons why this method will probably prove to be unsatisfactory. The handling of two sets of cans by the producers who bring milk to the factory requires more truck space than is necessary to carry the milk alone; the use of two sets of cans calls for constant inspection to guard against interchange, unless the cans are distinctly marked; individual farmers are not likely to raise enough hogs to utilize the maximum flow of whey because as the seasonal yield of milk decreases, it becomes necessary for them to provide increasing amounts of food for the hogs from other sources. A single hog farm designed to utilize the whey would have to be so located as to avoid complaint as a nuisance, and this might involve long hauls.

Drying.—In drying, 100 gallons of fresh whey are mixed with about 80 pounds of corn flour, bran or middlings or a mixture of them. When thoroughly mixed the thickened whey is pumped or allowed to flow by gravity upon slowly revolving steam heated rolls from which it is scraped, carried by a conveyor to a screen and the screenings bagged or barreled. One or two men are required to operate the plant depending upon the size of the factory and the steam demands for other purposes. Each 100 gallons of whey will produce about 124 pounds of dried product having a sales value of 5 cents per pound. The market, however, is not yet sufficiently developed to make possible the disposition of the dried product, if all of the whey were dried. If all dried whey produced could be sold at 5 cents per pound the present indications are that the process would more than pay for itself. The information concerning this process was provided by the Buffalo Foundry and Machine Company, of Buffalo, New York.

Chemical Treatment.—Because of the concentrated character of whey waste the treatment methods attempted have mainly been with chemicals. The high acidity, as high as 6500 p. p. m. for a dilute whey, must be overcome before the waste can be discharged upon soil, treatment beds or into streams.

The work carried out by the Faculty Committee of the College of Agri-

culture at Cornell University in 1920 and in 1921 indicated that the addition of enough lime to an undiluted whey to neutralize the existing acidity and to provide an excess of 35 per cent of lime, followed by heating to the boiling point, caused a curd to form which readily settled. The resulting supernatant was always turbid in character and frequently clogged the sand beds in warm or hot weather. "As measured by the organic nitrogen test, the nitrogen was reduced about 50 per cent by boiling and about 88 per cent by the sand filter, giving a total reduction of 94 per cent."[4] The curd when dried has a commercial value as stock food.

During the past summer (1929) two chemical precipitation plants for the treatment of diluted whey have been operated by the Sodus Coöperative Creamery Company, at Hannibal and Wolcott, New York. Each of the plants consists of a septic tank, which the company built about two years ago and which provides for a detention period of about three days, a mixing channel for hydrating the lime, a series of four hopper-bottomed precipitation and mixing chambers each 10 feet square and 10 feet deep, with one foot free-board, and a pump pit containing a small 2 or 4 horsepower centrifugal pump. In the Hannibal plant the pump is used to mix the fresh whey waste and the hydrated lime. In the Wolcott plant the pump serves both as a mixing device and as a sludge pump for delivering the chemical sludge to one of two cinder sludge-drying beds. At Hannibal the clarified effluent flows by gravity into a tile sub-surface drain system while at Wolcott it is discharged into a small stream or ditch. The lime at Hannibal is hydrated by the hand and hoe method, at Wolcott by an improvised mechanical mixer.

In operating these plants the cycle of operation begins during the afternoon. Whey waste is allowed to flow from the septic tank through the mixing channel into the first of the four mixing and precipitation chambers, and 95 per cent lime (CaO) is introduced into the mixing channel, slowly and with constant stirring, slightly in excess of that required to neutralize the acidity of the total volume of whey waste anticipated until noon of the following day. The flow of whey waste is then diverted from the mixing channel, and passes directly from the septic tank to the bottom of the first mixing and precipitation chamber at the same variable rate at which the waste leaves the factory. By introducing the septic whey waste at the bottom of the first precipitation chamber the acidity is more effectively neutralized and offensive odors more thoroughly overcome. The following morning, when the attendant begins the work of the day, he measures the depth of accumulated waste in the mixing chambers and estimates whether sufficient lime has been added the preceding afternoon. If it appears that more lime will be required by noon, such additional amount is added by hydrating as before in the mixing channel. At the same time the centrifugal pump starts circulating the contents of the precipitation chambers, drawing

from the last chamber of the series in use and discharging into the first chamber of the series. In this manner the waste is circulated and mixed for a period of about 4 hours. Fresh septic tank waste is continually entering the precipitation chambers during the mixing. Shortly before noon the flow from the septic tank is stopped, circulation by the pump ceases, and sedimentation of chemical sludge begins. For acidities of raw waste of 1000 p. p. m. settlement of sludge occurs in from one to two hours, but if the acidity is 6500 p. p. m. from three to four hours are required for sedimentation. After the period of sedimentation the sludge is drawn below the mouth of the clarified effluent lines and discharged upon the sludge beds. The clarified effluent is then discharged by gravity, the remaining sludge sent to the sludge bed, and the cycle of operation has been completed.

The amount of 95 per cent lime required ranges from 0.5 to 1.0 per cent of the weight of the raw waste when the acidity of this waste ranges from 1000 to 6500 parts per million.

The volume of sludge formed ranges from 10 to 25 per cent of the original volume of the waste treated. The sludge flows readily, dries well when exposed on cinder sludge beds, and is inoffensive. Analysis has shown it to have a value of $9.50 per ton as taken from the sludge bed. The sample analyzed had a moisture content of 46 per cent. The thoroughly dried sludge weighs from 0.6 to 1.25 per cent of the weight of the raw waste treated.

The clarified effluent is not stable and gives off an unpleasant alkaline odor, but the intensely disagreeable and penetrating odors of the septic tank effluent are not observed. Experiments with bleaching powder and with chlorine gas have shown that, where necessary, the unpleasant alkaline odor can be modified so as to be unobjectionable, but accurate quantitive tests of the amount of chlorine gas necessary have not yet been made. As judged by the organic nitrogen content and by its oxygen consuming capacity, the clarified effluent as compared with the raw waste shows a reduction of 86 per cent in organic nitrogen and 82 per cent in oxygen consumed.

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[2] *The Ohio Public Health Journal*, Vol. **7**, No. 7, July, 1916.

[3] "Studies on the Treatment and Disposal of Industrial Wastes. 4—The Purification of Creamery Wastes," U. S. Public Health Service, *Bulletin* **109**, 87 pages, 1920.

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[5] "Aeration Studies on Creamery Waste Purification," *Bulletin* **68**, Iowa State College of Agriculture and Mechanic Arts, Official Publication, Vol. **22**, No. 10, 39 pages, 1923.

[6] "The Purification of Skim-Milk Solutions on a Lath Filter," *Bulletin* **81,** Iowa State College of Agriculture and Mechanic Arts, Official Publication, Vol. **25,** No. 18, 30 pages, 1926.

[7] "Progress in Dairy Waste Treatment in Wisconsin," *Butter and Cheese Journal,* April 10, 1929.

Studies on the Treatment of Milk Products Waste.—Studies were carried out by E. F. Eldridge at the Michigan Engineering Experiment Station with the view of further developing methods of treatment of milk products wastes, to discover their limitations and to determine where each method is most applicable.

The methods of treatment studied were: (1) Septic tank treatment. This type had to be abandoned because of odors and scum troubles. (2) Septic tank treatment followed by filtration. The rapid souring of the milk produced an acid condition unsuitable for treatment on biological filters. (3) Filtration with no preliminary treatment. A small laboratory filter constructed of lath and first tried out by Dr. Max Levine produced satisfactory results for general application. (4) Activated sludge. This process is limited to large plants by reason of cost. (5) Broad irrigation was effective but it is rarely practicable. (6) Chemical precipitation. A clarified effluent was obtained with ferrous sulphate and lime. Four pounds of ferrous sulphate per 1000 gallons was the minimum quantity for proper treatment. Lime or caustic soda must be added in quantity sufficient to give a phenolphthalein alkalinity. If the waste is fresh, less lime is needed for floc formation when the copperas is added first. The reverse order of application is necessary if the waste is sour. A complete removal of oxygen-consuming materials does not seem possible. The sludge does not dry readily or completely on sludge beds. (7) Chemical precipitation followed by filtration. Between 70 and 80 per cent of the oxidation took place in the upper four feet of filter. The reduction depended largely upon the strength of the raw waste. The oxidation of milk sugars was complete. The oxidation of the nitrogen compounds followed that of the carbohydrates and proceeded at a lower rate. Indications are that each square foot of filter area will handle a quantity of waste requiring about 43 grams of oxygen per day based on the oxygen consumed determination.—*Bulletin* **24,** Michigan Engineering Experiment Station, Vol. **5,** No. 1, July, 1929. (Abstracted by E. J. Theriault.)

The Natural Purification Capacities of Streams[1]

BY H. W. STREETER[2]

In most problems of stream pollution, and especially in those involving the safeguarding of water supplies, the protection of fish life, or the prevention of conditions offensive to riparian dwellers, the capacity of streams for natural purification is a vital factor, failure to take proper account of which, in planning remedial measures, may lead either to economic waste, if such capacity be underestimated, or to failure of these measures, or even possible disaster, if it be overestimated. It is the purpose of this paper to note some of the major factors which influence the natural purification capacities of streams, to indicate roughly the nature and extent of changes in certain measurable characteristics of polluted stream waters brought about by natural purification agencies, and to point out some of the applications which may be made of our present knowledge of these changes in estimating the relative amounts of protection afforded by natural and artificial safeguards, in specific cases.

In discussing this subject distinction should be made, for practical purposes, between two kinds of natural stream purification, namely: (*a*) that which is concerned with the changes taking place in the bacterial flora, particularly those introduced into streams through the medium of sewage and certain other wastes, and (*b*) that which refers to the biochemical oxidation of putrescible organic matters and the maintenance of an adequate reserve supply of dissolved oxygen in the stream water. The former ordinarily is termed "bacterial" purification and the latter may be denoted conveniently here as "biochemical" purification.

Factors Influencing Natural Purification

Inasmuch as all of the changes incidental to natural purification in streams are progressive ones, time is a factor of major importance in these changes, regardless of the kind of purification considered. In a natural body of water, distance is significant only in relation to the time of passage of water from one point to another. In a flowing stream, the time of flow between two fixed points may vary widely with the conditions of flow; hence the degree of natural purification occurring between these two points will correspondingly vary.

In the bacterial purification of streams, an initial increase in the density of bacteria has been observed to take place in distances extending below points of major pollution corresponding to times of flow of from 10 to 15 hours, after which a progressive decrease occurs along a well-defined curve

[1] *Presented before North Carolina Sewage Works Association, High Point, Nov. 5, 1929.*

[2] *Sanitary Engineer, U. S. Public Health Service, Cincinnati, Ohio.*

until a minimum density is reached, probably representing the normal bacterial content which a particular stream will support. It is not definitely known whether this initial increase is due to an actual multiplication of bacteria or to a progressive disintegration of coarser particles of suspended matter containing large numbers of bacteria. For all practical purposes, however, it is unnecessary to consider here the probable reason, as our interest lies mainly in the reduction of bacteria occurring after their maximum density has been reached.

The general type of reduction curve shown in plots of the bacterial content of polluted streams below points of maximum bacterial density

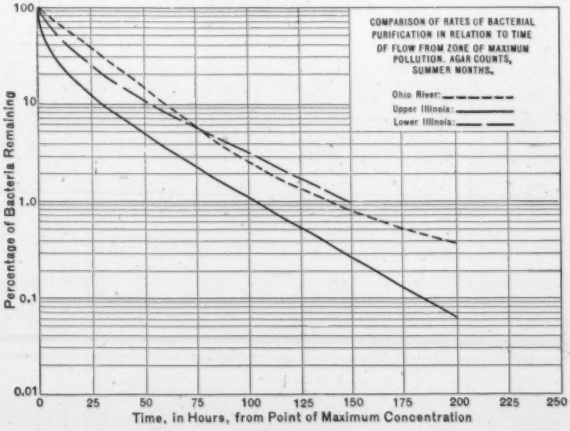

FIG. 1.

(Reproduced, by permission, from *Trans. Am. Soc. C. E.*, **89**, 1372 (1926), Fig. 12)

is illustrated by those observed in the Ohio and Illinois Rivers,[1] in which the abscissa scale is that of time of flow below the maximum point and the ordinate scale a logarithmic one giving the residual bacteria after various times as percentages of the initial maximum (Figure 1). Although the two curves based on observations in the Ohio and lower Illinois Rivers follow each other closely, they both diverge considerably from the curves illustrating conditions observed in the upper Illinois, where the density of bacteria is much higher than in the Ohio or the lower Illinois. When the three curves are redrawn on a basis of equivalent bacterial densities, however, they follow much more nearly the same general trend, indicating

[1] See *Public Health Bulletins* **143** and **171**, *U. S. Public Health Service.*

that a second factor, namely bacterial density, probably exerts an important influence on the rate of bacterial self-purification (Figure 2).

The effect of a third factor, seasonal or temperature change, on the rate and extent of bacterial purification observed in streams is illustrated by a comparison of B. coli reduction curves observed in the Ohio River under summer and winter conditions, respectively (Figure 3).

Other factors modifying the shape of the bacterial reduction curve are sedimentation and scour, which tend to depress or to elevate the curve, according to which one of these two opposed forces may predominate at a given time. It also is likely that the presence of some dissolved gases

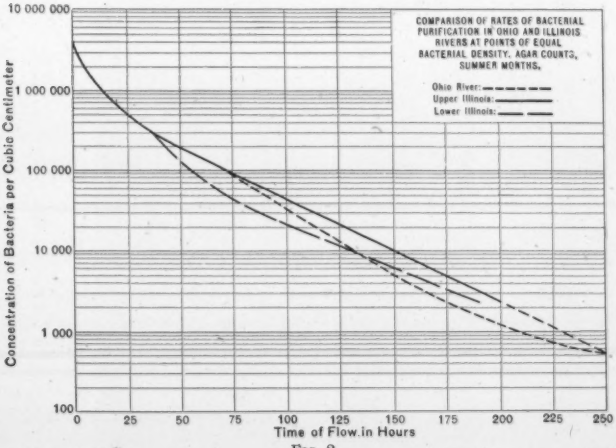

FIG. 2.

(Reproduced, by permission, from *Trans. Am. Soc. C. E.*, **89**, 1372 (1926), Fig. 13)

and mineral substances, as well as the activities of certain bacteria-consuming plankton, are powerful agents in the natural bacterial purification of streams, though the extent to which these factors may modify the normal reduction curve, under some circumstances, or actually may contribute to its normal form, is not sufficiently well established to justify any generalization. Of the dissolved gases, oxygen undoubtedly is the most important in this connection, as it is essential to the maintenance of the aerobic conditions which favor natural purification. The presence of excessive amounts of certain minerals, notably acids and acid metallic salts, has been shown to have a bactericidal effect, but also to kill plankton, which aid in natural purification. It also is probable that starvation

and a generally unfavorable environment account for a considerable proportion of bacterial reduction, in so far as it is concerned with sewage bacteria. Under average conditions, the time-density curves to which reference has been made probably represent fairly well the normal course of bacterial purification.

The "biochemical" self-purification of streams may be said to consist, first, of the progressive oxidation of certain oxidizable organic matters

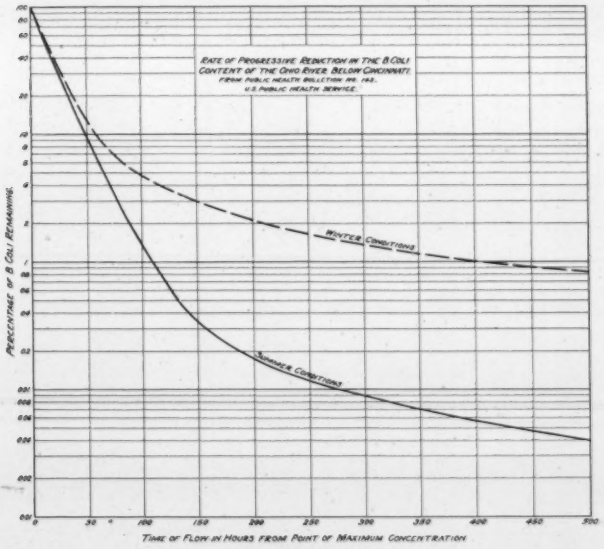

FIG. 3.

(Reproduced, by permission, from *Public Health Reports, U. S. Public Health Service*, June 15, 1928, Reprint No. 1232, p. 9, Fig. 1)

forming part of the normal constituents of sewage-polluted streams, and second, of the replenishment of the dissolved oxygen supply of such streams through atmospheric reaeration, or absorption of oxygen from the atmosphere, and also, under certain conditions, through the activities of oxygen-producing plants. Although these two phenomena are distinct in their modes of action, the latter is dependent on the former to some extent, in that the rate of absorption of oxygen from the atmosphere by polluted bodies of water is dependent in part on the rate at which dis-

solved oxygen is withdrawn from the stream water to support the oxidation of organic matter. Let us consider first the phenomenon of biochemical oxidation.

Although our present knowledge of the mechanism of this phenomenon is incomplete, we know that it is carried out through the activities of certain classes of aerobic bacteria, which, in the presence of oxygen, break down the carbohydrates and protein substances of certain organic matters into readily oxidizable materials, the end products being fairly simple inorganic substances, including carbonic acid, ammonia, nitrites and nitrates. In order that the oxidation may proceed, the three elements, oxidizing bacteria, oxidizable organic matter and oxygen, must be present. In the absence of oxygen some directly oxidizable substances, such as hydrogen sulphide, may be formed, but apparently by a different class of bacteria (anaerobes).

The earlier work of Adeney and, more recently, of Theriault,[1] has shown that the oxidation of the organic matters contained in sewage-polluted bodies of water proceeds in two distinct stages. The carbonaceous matter is oxidized in the first stage and the nitrogenous organic matter in a second stage. Theriault has shown that under laboratory conditions the time required to complete the primary, or carbonaceous stage, is about 10 days at 20° C. and is shorter, or longer, than this period according to whether the temperature is higher, or lower, than 20° C. Under the conditions of the ordinary 5-day B. O. D. test, the oxygen demand of fresh sewage or of freshly polluted river water probably always falls within the carbonaceous stage of oxidation. The corresponding oxygen demand of a well nitrified sewage effluent, or of a stream water in an advanced state of nitrification, conceivably may fall, however, in the secondary or nitrification stage, or in the transition zone between the two stages.

The main source of oxygen for maintaining the biochemical oxidation process is atmospheric reaeration, or absorption of oxygen by the stream directly from the atmosphere, though under some conditions the photosynthetic action of oxygen-producing plants may be an important factor. The atmospheric reaeration of streams, being wholly a physical action, is subject to the physical laws governing the absorption of gases by liquids. Empirical study of this phenomenon in streams has shown that the rate of reaeration is proportional to the deficiency of the dissolved oxygen content below saturation and is controlled also by temperature, by stream depth and by the various channel and flow conditions which affect the turbulence of flow, such as, for example, velocity, slope and roughness of the channel.[2] As the physical conditions governing the rate of reaeration

[1] *Public Health Bulletin* **173,** U. S. Public Health Service.
[2] *Public Health Bulletin* **146,** U. S. Public Health Service.

vary widely in different streams, and often in the same stream at different times and places, the rate of reaeration varies accordingly. In many cases, it is the principal limiting factor in determining the capacity of a stream for natural biochemical purification, as the oxidation of organic matter cannot proceed any faster than the rate of replenishment of the oxygen supply.

The net rate of change in the dissolved oxygen content of a polluted stream is determined, at any given time, by the resultant of the two opposing rates, one of deoxygenation and the other of reaeration. In a simple case, the resultant curve of dissolved oxygen, when drawn on a time basis, is the familiar "sag" curve frequently observed in streams below points of major pollution (Figure 4). The shape of this curve, reflecting the rate of oxygen loss and recovery, is modified, of course, by

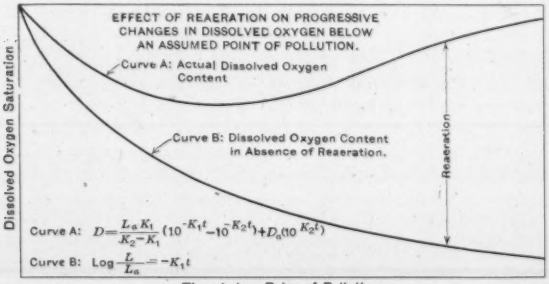
EFFECT OF REAERATION ON PROGRESSIVE CHANGES IN DISSOLVED OXYGEN BELOW AN ASSUMED POINT OF POLLUTION.
Curve A: Actual Dissolved Oxygen Content
Curve B: Dissolved Oxygen Content in Absence of Reaeration.
Reaeration
Dissolved Oxygen Saturation
Curve A: $D=\frac{L_a K_1}{K_2-K_1}(10^{-K_1 t}-10^{-K_2 t})+D_a(10^{-K_2 t})$
Curve B: $\text{Log}\frac{L}{L_a}=-K_1 t$
Time below Point of Pollution

FIG. 4.

(Reproduced, by permission, from *Trans. Am. Soc. C. E.*, **89**, 1355 (1926) Fig. 5)

the oxygen demand, the "sag" portion being deeper and more prolonged in the presence of greater amounts of oxygen demand. It also is modified by temperature, which influences both the rate of deoxygenation and that of reaeration. If several increments of polluting material are added to a stream before the cycle of oxygen recovery can be completed, the oxygen curve may pass through successive depressions, each deeper than the preceding one.

The relation existing between the oxygen supply and oxygen demand at any given time is sometimes denoted as the "oxygen balance." If the supply momentarily exceeds the demand, the balance is positive; if the demand exceeds the supply, it is negative. In this connection, it should be emphasized, however, that a positive oxygen balance may be only a temporary one, as the future draft on the oxygen supply represented by

the unsatisfied oxygen demand may exceed the present supply on hand. The situation in this respect has been likened, in financial terms, to one of temporary solvency, with obligations, in the form of unsatisfied oxygen demand, maturing on the morrow. If such solvency is to be maintained, fresh receipts, in the form of a further supply of dissolved oxygen, must be added to the asset side of the ledger through the medium of reaeration, otherwise a condition of negative balance, or oxygen bankruptcy, ultimately may be reached.

The main factors involved in the oxygen balance are reaeration, on the positive side of the balance sheet, and the oxygen demand of the liquid portion of the stream, of the flowing solids and of the sludge deposited on the channel bottom, respectively, on the negative side. In highly polluted streams of sluggish flow the oxygen demand of sludge deposits during the warm season may be a very large factor in the total deoxygenating power of the stream.

Practical Considerations

Although our knowledge of the various factors governing natural purification phenomena is still far from being sufficiently complete or generalized to permit accurate estimates, applicable to any given set of conditions, to be made of the self-purification capacities of streams in general, it is approaching a state wherein estimates precise enough for practical purposes are possible in cases where certain facts regarding the physical conditions of pollution and rates of natural purification of given streams can be established through preliminary surveys.

In cases involving estimates of the extent to which the bacterial pollution of a stream should be reduced in various zones in order to protect given sources of water supply, it is helpful to construct tables and charts[1] showing the actual sewage-contributing population in each zone and the proportionate effect of each respective population group on the total pollution of the river at each downstream water intake. In general, such charts will show clearly the particular zones in which stream cleaning measures will produce the most effective results at given downstream points (Figure 5).

Wherever the maintenance of an adequate minimum reserve of dissolved oxygen in various zones of a stream is the primary objective of stream sanitation, the main problem involved is that of reducing the oxygen demand of wastes discharged into the river at various points to an amount sufficient to maintain an adequate minimum reserve supply of dissolved oxygen, taking due account of the natural reaeration capacity of the particular stream. In order to estimate the required degree of reduction,

[1] For examples, see *Public Health Reports*, June 15, 1928, reprint 1232. Table 1 and Figs. 2 and 3, pp. 10, 11 and 12.

it is necessary to determine, or assume, rates of reaeration under limiting flow conditions, and to make trial computations for critical river stretches,

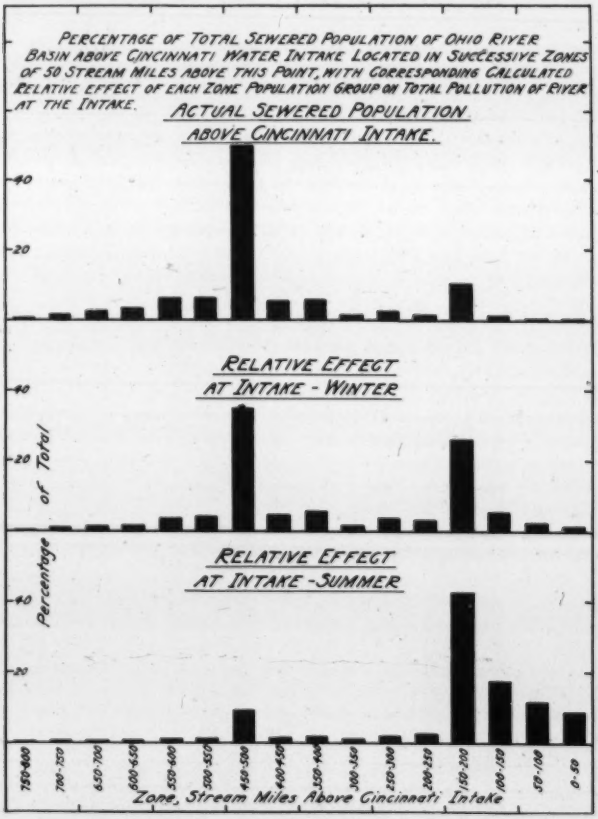

FIG. 5.

(Reproduced, by permission, from *Public Health Reports, U. S. Public Health Service*, June 15, 1928, Reprint No. 1232, p. 12, Fig. 3)

showing the progressive changes in dissolved oxygen with various assumed oxygen demand values. If the factors assumed in the computation are

correct, the resulting dissolved oxygen curves will show approximately the maximum permissible oxygen demand consistent with maintaining a specified minimum dissolved oxygen content in a given river stretch.

In considering the various possible measures of sewage treatment which are available for reducing the pollution of streams, it is desirable to bear in mind that the main function of an artificial process of sewage treatment is to reinforce the natural purification capacity of the watercourse into which a particular effluent is to be discharged, having due regard for the particular kind of natural purification which is of primary importance in a given case. In estimating the probable effect of sewage treatment on conditions of pollution and natural purification in a stream, proper account should be taken of the extent to which a reduction of the density of pollution may modify the rate of natural purification in river stretches lying downstream from the points at which such reduction may be applied. It has been noted previously in this paper that the rate of natural purification of streams apparently is diminished in proportion to the density of pollution, all other things being equal. Under these circumstances, a given degree of reduction in the density of pollution of a stream at one point possibly would fail to bring about a proportionate decrease at points located downstream. By shifting the base line along the natural purification curve to a point corresponding to the reduced initial density of pollution, a rough approximation to the expected new rate probably can be made in most cases.

Another point which should be emphasized in this connection is that the application of sewage treatment for the purpose of reducing stream pollution can be effective only with respect to that portion of the total pollution of streams originating in sewered population groups. In many cases, an important element in the total pollution of water courses is that portion which is derived from unsewered communities and rural agricultural areas. It further may be noted that inasmuch as the capacity of sewage treatment works usually is limited, in this country, to volumes of sewage not greatly exceeding the dry weather flow, considerable amounts of untreated or only partially treated sewage may be discharged into streams from sewered areas during periods of storm flow. In estimating the probable effect of artificial stream-cleaning measures, attention should be given to these factors.

As regards the efficiency of various processes of sewage treatment, it may be of interest to set down here some rough limiting figures, taken from standard texts on the subject. These are as follows:

Among the various combinations of the eight processes of sewage treatment enumerated, those involving plain sedimentation, trickling filters or activated sludge treatment, final sedimentation and chlorination, or plain sedimentation, intermittent sand filtration and chlorination, would

	Percentage Reduction		
	Suspended Matter	B. O. D.	Bacteria
(1) Fine screening	15–20	...[a]	15–20
(2) Plain sedimentation	50–75	40–50	50–60
(3) Chemical precipitation	80–90	70–80	80–90
(4) Trickling filters	30–40	80–85	90+
(5) Activated sludge	80–90	85–90	90+
(6) Intermittent sand filters	95+	...[a]	98–99
(7) Final settling tanks	50–70	...[a]	50–70
(8) Chlorination	0	15–35[b]	95–99

[a] No satisfactory data at hand.

[b] From data cited by L. H. Enslow, *The Engineering Journal (Canada)*, March, 1929.

appear, on the basis of the percentage efficiencies given, to be capable of producing from an assumed normal sewage containing about 10,000,000 *B. coli* per 100 cc., final effluents having *B. coli* indices ranging below 25,000 per 100 cc. With a combined dilution and natural purification factor exceeding five, this would leave a residual *B. coli* index in the stream, due to these particular effluents, not exceeding 5000 per 100 cc., which would not be expected to overburden the average efficiently operated water purification plant. For fine screening, or plain sedimentation, in combination with chlorination, the required dilution and natural purification factor would be considerably higher, ranging as high as 80 for fine screening and chlorination and 25 for plain sedimentation and chlorination, on the basis of minimum efficiencies.

By a similar process of calculation, it may be estimated that combinations of plain and final sedimentation with trickling filters or activated sludge treatment, should produce, from an assumed normal sewage having a B. O. D. of about 300 p. p. m., final effluents having a B. O. D. less than 20 p. p. m., the limit fixed by the British Royal Commission standard.

In conclusion, it perhaps may be well to emphasize that the natural purification capacity of streams, though constituting an asset of tremendous importance, is surrounded by certain limitations, both in its extent of action and in its degree of constancy under various physical and biological conditions which are not subject to artificial control or, in some cases, to reliable forecast. In undertaking to utilize this asset as an integral part of stream sanitation programs, the limitations noted should be defined and evaluated as accurately as possible in each case. Thus utilized, natural purification becomes a powerful ally of artificial methods of stream pollution control, such as water and sewage treatment. The day is rapidly approaching, in fact, when these three measures of protection will be used in conjunction with nearly the same degree of intelligence and definiteness of purpose with which the modern bridge-builder fits his different members into a harmonious structure. For those who are concerned with stream sanitation in its various aspects,

a good example is to be found in the bridge engineer who uses a definite and liberal factor of safety and designs his structure to sustain the maximum load. With the increasing stress being imposed on the natural purification capacities of our streams and the consequent reduction in the margin of safety hitherto inherent in them, a general tendency toward the adoption of more rigid standards for the efficiency of water and sewage treatment is being evidenced. For the designer and plant operator, this tendency means larger responsibilities and an ever-broadening horizon of knowledge and experience.

Biological Changes in Sewage Polluted Streams.—Mr. R. W. Butcher, Asst. Naturalist of the British Ministry of Agriculture and Fisheries, has reported results of studies of the Chess and Lark rivers. Both rivers receive the effluent from sand filters, and the River Lark receives, in addition, the effluent from a beet-sugar factory. The predominant organism in both rivers is *Sphaerotilus natans*, followed by *Leptomitus lacteus*, and *Carchesium*. The growth of these organisms is promoted by partially-decomposed sewage, silk wastes, sugar-beet wastes and other industrial wastes. Growth on the river bed changes from clean-water forms found on stones, such as water shrimps, snails, May-fly and their larvae, through water lice, clams and a few varieties of snails found on slightly-polluted mud bottoms, to the tubifex worms and gnat larvae found in putrefying sludge. Clean-water forms take refuge in the weeds when driven from the bottom mud by encroaching pollution. Studies of the River Lark below the point of entry of the sugar-beet wastes showed increasing numbers of pollutional forms, which were tabulated and photographed.

"Whatever stage the organic matter is in it will act as a fertilizer for some organism." Microscopic organisms react to chemical changes undetected by the usual methods of analysis. Effluents low in nitrates promote the growth of diatoms; more concentrated nitrates stimulate the growth of blue-green algae (*Oscillatoria*), *Euglena*, and filamentous algae known as "blanket weed" (*Cladophora* and *Vaucheria*), which can often grow to such an extent as to hinder navigation or fishing.

Fish life may be repressed if sewage concentration results in loss of organisms used by them for food. The resistance of fine and coarse fish varies greatly.—*Proc. Assn. Managers of Sewage Disposal Works*, pp. 168–185, 1928.

Control of Stream Pollution in Pennsylvania[1]

BY W. L. STEVENSON[2]

The resolution adopted by the Pennsylvania Sanitary Water Board in 1923 for the classification of streams into three classes, designated A, B and C, is one of the basic policies for the guidance of the Board in many of its problems.

According to the original resolution, Class A streams were those unpolluted from any artificial source. Recently the resolution was revised so as to divide Class A streams into two kinds; namely, Class A-1 and A-2.

Class A-1 streams are the same as the original Class A. Class A-2 streams are those which, although subject at some point to minor pollution, have through natural processes of purification become relatively clean and pure again at a point farther downstream or through the artificial purification of the polluting substance prior to its discharge into the stream, are unharmed thereby. It was estimated prior to the revision of this resolution that there would be found about 24,000 miles of strictly Class A streams in Pennsylvania, but under the revised resolution the total mileage of relatively clean and pure streams will be very much larger.

Class C streams are those not now used as sources of public water supply, which will not support fish life and which it is not now to the interest of the Commonwealth to attempt to restore to a cleanly condition. As yet no streams have been designated in this class and it is anticipated that such action will be taken only in the case of main drainage streams in the coal fields.

The real problems of the Board are found in the Class B streams. The resolution states that the degree of treatment of sewage or industrial waste discharged thereto will be determined after a consideration of

(*a*) the present and probable future use and condition of the stream,

(*b*) the practicability of remedial measures,

(*c*) the protection to the public health and other public uses of the stream, and

(*d*) the economics of the case.

Typical public uses of a stream are navigation, watering stock, development of power, as sources of water for steam raising purposes or processes of manufacturing and as a source of public water supply for drinking and municipal purposes, this last use being the highest and dominant.

The Board also recognizes the increasing interest of the public in the recreational use of suitable streams.

The word "condition" in the resolution includes its sanitary quality as

[1] *Presented at the Third Annual Conference of the Pennsylvania Sewage Works Association, Harrisburg, Pa., July 16, 1929.*

[2] *Chief Engineer, Pennsylvania State Department of Health.*

determined by chemical or bacteriological examination and its physical features, such as high velocity or sluggish velocity as affected by dams creating pools.

For the treatment of municipal sewage there have been established practicable processes whereby any required degree of treatment may be attained. Therefore, the practicability of obtaining treatment of municipal sewage is largely a matter of engineering design, municipal finance, construction and operation. Of these, municipal financing is the most difficult factor. The Constitution of Pennsylvania has fixed a maximum limit of municipal borrowing capacity, and bond issues in excess of 2 per cent of the assessed valuation of property must be authorized by the electorate, who generally look with more favor upon authorizing bond issues for their own benefit, such as improved highways or school buildings, rather than for sewage treatment, which in the last analysis is usually for the benefit of down-stream riparian owners or users of the water.

In order that the Sanitary Water Board may determine the proper degree of treatment of sewage or industrial waste, it maintains five mobile laboratories, each in charge of a competent chemical engineer. Gauging stations are located on streams to be studied and sampling stations are selected at critical points. During the warm weather when stream flows are low, these mobile laboratories take samples of the waters of rivers under study for immediate analysis in the field. Bacteriological samples of the river water, preferably at waterworks intakes, also are taken to determine the load of sewage organisms in the raw water.

The Board after having received reports based upon such field studies is able to erect uniform policies along any given stream as to the required degree of treatment of municipal sewage, and thereafter the engineers for the Board endeavor to coöperate with the municipalities in question to negotiate financial programs for the progressive construction of the needed intercepting sewers, pumping stations, treatment works and the like.

But after this has been done and pending the completion of the projects, the public is not satisfied because it still sees sewage pouring into the stream without any treatment. Nevertheless the fact remains that more is and will be accomplished through such equitable policies and these progressive programs than was accomplished when the State issued to municipalities orders "to forthwith" carry to completion such large projects as are involved in the complete treatment of municipal sewage.

Turning to the subject of industrial wastes, we are confronted with an entirely different problem from that of sewage disposal, for as Doctor Appel has said, relatively few industrial wastes have a direct prejudicial affect upon public health—that is, they are not, *per se*, disease transmitting. There is, however, one industrial waste which indirectly could affect the public health, namely, phenolic waste waters from by-product coke ovens.

This is because they are capable of producing offensive tastes and odors in public water supplies after chlorination, with the result that the water consumers turn to other supplies, but this vexatious problem has practically been solved through coöperation with the by-product coke industry.

Reasonable and practicable ways and means for the treatment and disposal of most industrial wastes are not known. For the solution of this vexatious problem the Sanitary Water Board inaugurated what is believed to be a new policy in the United States; namely, the coöperation of the State authorities with industry in groups for a pooling of knowledge and coöperative effort to find solutions of these unsolved problems.

Such work began in 1924 when an agreement was made with companies operating leather tanneries in Pennsylvania, under which a fund of $75,000 was made available to a Committee consisting of technical representatives of the leather tanners and of the State. The investigatory work was first done in a laboratory and then a full scale experimental tannery waste treatment works was constructed and operated. Studies were made of twelve miles of stream below this plant in order to determine the assimilating power of the stream for tannery wastes untreated and treated to various degrees.

A solution of this heretofore unsolved problem is nearly in sight as the Committee has found processes which at reasonable cost reduce the settleable solids and the organic content of tannery wastes about 70 per cent. The further purification of the settled effluent, while successful from the point of view of the scientist, would be entirely unsatisfactory to the public inasmuch as tannic or gallic acid in the effluent apparently combines with iron and yields an effluent of a bluish-black color. Studies are now under way to eliminate this difficulty either through decolorization or through the use of filter media containing little or no iron.

The next group to be approached by the Board was the pulp and paper industry. Again an agreement was made which created a committee, consisting of technical representatives of both the State and industry, which is in charge of research work being done in seven laboratories. Studies have also been made of streams below paper mills, and the efficiency of full-scale treatment devices in actual operation in mills has been studied both to determine their efficiency and improve them if possible. One of the outcomes of this study is that except in certain kinds of mills, there is no reason why proper and efficient savealls for white water should not be operated.

One of the most important coöperative agreements was that which the Board made with companies operating by-product coke ovens. This industry on its own initiative devised and installed and operates efficient devices either for elimination or substantial treatment of its phenolic waste waters. But in all man-operated devices of this kind there is always possibility of an accident and so the agreement provides that the companies' parties thereto shall maintain their devices in a state of efficient operation,

and if and when an accident occurs which permits a spill of phenolic wastes to a stream, the company shall give immediate notice to the State Department of Health of the accident, immediately adopt emergency remedial measures and make prompt repair of the break. When such notice is received, it is not only sent to waterworks below the point of spill in Pennsylvania, but also on interstate streams to the Health Departments of the downstream states in order that that Department in turn may give warning to its waterworks.

This system of notice and warning under our agreement has minimized to an almost negligible degree the presence of offensive tastes and odors in water supplies formerly caused by accidental spills.

The Sanitary Water Board has entered into an agreement with companies operating manufactured gas works along practically identical lines as the coke agreement and for the same purpose.

Engineers of the Sanitary Water Board and of the Water and Power Resources Board have been holding meetings with engineers representing the anthracite coal industry in an effort to reduce the culm discharged from breakers in the anthracite coal field.

Negotiations are under way for a coöperative study of the tremendous problem of disposal of mine drainage in the bituminous coal fields. This is probably one of the largest problems before the Sanitary Water Board so far as miles of streams affected is concerned. At the present time there is no reasonable and practicable method for neutralizing and softening the coal mine drainage. Only a part of the bituminous coal fields of Pennsylvania have been developed and unless some practicable and economically possible plan can be evolved whereby the now clean streams draining the undeveloped coal fields can be protected and simultaneously not prejudicially affect the mining of bituminous coal in Pennsylvania, an alarmingly large mileage of now relatively clean streams will be irredeemably ruined in a few generations.

It is earnestly hoped that through constructive coöperation between the bituminous coal industry and the Sanitary Water Board some practical plan will be evolved to avert this evil day.

Of necessity, because of limitation of time, the above is but a rambling statement and only hits the high spots in the work of the Sanitary Water Board. The problems are big ones, and the conditions now existing are the result of intense municipal and industrial development in Pennsylvania for long years. It is utterly impossible to solve these problems immediately. The Sanitary Water Board is constructively approaching its task, always having in mind the present and future well-being of the people, of the municipalities and of the industries of this great Commonwealth.

Editorial

Mechanism of the Activated Sludge Process

In the voluminous literature that has accumulated with the development of the activated sludge process, it is rather remarkable to note the comparative lack of fundamental research on the properties of the sludge with regard to its function in the process of purification. Undoubtedly the reason for this lack of information is the difficulty of the problem. An investigation of the mechanism of the process must comprise a correlation of facts developed by bacteriological, physical, chemical and biological research of the highest quality. The laboratory results must be interpreted by one thoroughly familiar with the practical details of the operation of a modern activated sludge plant.

A few investigators have indicated that in their opinion all of the properties of activated sludge could be explained by laws of physical and colloid chemistry, but it is generally recognized that biological and bacteriological phenomena must play an important part in the mechanism of the process. While it must be true that adsorption and coagulation of colloids occurs on the surface of the flocs, it also appears that this action cannot be continued indefinitely unless the sludge be re-activated.

A very reasonable theory of the mode of action of activated sludge was published in *The Surveyor*, Sept. 9, 1927, by Parsons and Wilson of Reading, England. They consider the action to consist of a stage of clarification in which the surfaces of the sludge flocs adsorb the colloidal solids of the sewage, and show by results of experiments that the Freundlich adsorption equation holds for well-activated sludge. The surfaces of the flocs soon lose their adsorptive properties, however, if biological oxidation is lacking. Parsons and Wilson suggest that this subsequent oxidation is obtained by re-aeration of the sludge. Whether or not this is the most economical way to re-activate the surfaces has not as yet been definitely established. Further work on oxygen relations is needed to determine whether there is a sufficient degree of saturation of oxygen, if any, in the more concentrated sludge to accomplish the necessary oxidation and reactivation of the sludge flocs more efficiently than such oxidation can be accomplished in contact with sewage.

Biological oxidation infers the presence of enzymes, which have long been considered to be of importance in the mechanism of the action of activated sludge, but which have not been studied thoroughly. It is

probable that a complete study of the relation of enzyme action to the activation of sludge would yield valuable data.

Studies of the biology of activated sludge have probably been more extensive than those of its biochemistry or bacteriology. Some authorities believe that the properties of activated sludge depend on the presence and action of certain larger microörganisms, plankton and protozoa. Others, possibly in the majority, believe that such higher organisms are adventitious or incidental to the true functions of the sludge. It may be that a symbiotic relationship exists between the bacteria and the bacteria-eaters similar to the conditions found by Purdy, Theriault and Butterfield in their study of the mechanism of oxygen utilization in sewage and synthetic organic liquors.

Less work has been done on the bacteriology of activated sludge than on its planktology or physical chemistry. The great difficulties of bacteriological studies of activated sludge have deterred all except a few investigators, and their results have not been very enlightening. The mechanism of the process of biochemical oxidation of the surfaces of the sludge flocs can be explained only by a study of the bacteria and enzymes responsible for such oxidation, assuming that a purely chemical oxidation is unlikely.

From a practical standpoint, we do not as yet have a reasonable or complete theory to determine the optimum amount of sludge to be returned to the incoming sewage, either on a volumetric or gravimetric basis. The experience of all operators indicates that the results of volumetric tests of sludge concentration are too variable to serve as a basis of control of the aeration process. Gravimetric determinations of suspended solids in the mixed liquor in the aeration tanks are of considerably more value, and such tests are now usually made daily in most large plants. The theory of surface adsorption of colloids indicates that the activated sludge should be maintained at comparatively high concentrations, provided large amounts of sludge do not demand oxygen to such a degree that this disadvantage outweighs the advantage of the presence of large surfaces. A study of these opposing factors should be very enlightening. Basiakine, in Moscow, several years ago claimed that the limiting factor for activated sludge purification was analogous to the limiting factor for stream purification, namely, speed of absorption of oxygen from the atmosphere. Basiakine's theory was developed to a large extent on the basic work done by Phelps and Streeter. The theory of the so-called "stream-flow process" advocated by Jenks and Levine was based on a rational development of the principles of de-oxygenation and re-aeration. Further work on similar lines is of theoretical interest and practical value. Refinements in methods of control of activated sludge plants and economies in operating costs may follow as a consequence of more complete knowledge of the oxygen requirements of activated sludge.

Romance in Sewage Disposal

The romantic or emotional aspects of science have in general been emphasized to a greater extent in France than in England or America. The Englishman or American in technical or scientific work is more or less prosaic and characterized primarily by curiosity or inquisitiveness rather than by lofty thoughts of his contributions to culture or humanity.

Notwithstanding this characteristic, we occasionally find writers who attempt to cast glamour over the unadorned facts of garbage disposal, sewage treatment and sludge disposal. Some of these bedtime stories are entertaining as witness the following editorial from a recent issue of *The Surveyor:* "The Salubrious Dump: its Flora and Fauna."

"In an article entitled 'The Botany of Refuse' the *Times* deals with 'these huge, evil-smelling piles' which the metropolis has in unneighborly manner inflicted upon Home Counties' residents. But it treats the subject from an entirely new standpoint—that of the botanist, 'who finds the rubbish heaps of a great city a perennial source of interest.' The reference is particularly to the tangle of vegetation which covers the refuse within a few months of its being tipped, and it is interesting to hear that 'most of the plants in the tangle are of foreign origin, and one may find among them species from every quarter of the globe.' A list of foreign plants found in such places round London contains no fewer than 250 species, but we personally prefer to do our own botanizing on the swards and among the hedgerows of country lanes. We are content to leave the botanist in full possession of his 'sneaking affection for these dumps,' and to ally ourselves with the party to whom they cause 'such natural offense.'

"Some years ago a gentleman whose sanitary enthusiasm outran his sense of the ridiculous, wrote an article which he called 'The Romance of Sewage Disposal,' in which he pictured the dear little microbes marrying and giving in marriage, and within the precincts of their unsavory habitat multiplying by millions and thriving upon a diet of very mixed salubrity. It was just the mental pabulum for the popular weeklies which dabbled in the wonders of science among other things, and we believe that the author was commissioned to write many more articles in similar vein. Regarded in the right light, there is a certain spice of romance in everything, although much depends upon the actual interpretation of the word. There may be some hidden romance in the dumps (there is at least beauty in their vegetation) but it has yet to be discovered. Meanwhile we would suggest to the gentleman who penned the *Times* article that he should turn his attention to the fauna of the dumps. Local color could be acquired by the simple expedient of a night spent upon them. One would be enough."

The fauna of sludge dumps was discussed at the New York meeting, as reported in this issue; a fly paper comes from California; odors have been

wafted from Schenectady and Plainfield. These discussions are hardly romantic, but nevertheless such problems are familiar to most of us, and their solution usually demands true scientific research and mature engineering judgment.

Whether or not we are able to find romance in our work, the fact remains that the work must be done and we are able to find satisfaction in some of its aspects. Possibly our philosophy may best be expressed in the words of the drain man, Robert Smith, in Charles Rann Kennedy's "The Servant in the House:"

"That's what I come 'ere to talk abaht—my job. P'r'aps you'll think as it ain't a tasty subjic, before a lot o' nice, clean, respectable people as never 'ad anythin' worse on their fingers than a bit o' lawn dirt, playin' crokey; but some one 'as to see to the drains, some one 'as to clear up the muck of the world; I'm the one, an' I'm 'ere to tell you abaht it."

Progress toward Clean Streams

The alleviation of stream pollution is usually the incentive for treatment of sewage and industrial wastes. The technical and administrative difficulties in determining proper standards of stream cleanliness, as correlated with varying degrees of treatment of sewage, have inspired widespread studies, of which the most notable are those of the U. S. Public Health Service, described by Mr. Streeter in this issue (p. 131). The problems of the Sanitary District of Chicago are of world-wide interest. The Pennsylvania Sanitary Water Board has introduced new ideas and policies in the administrative field of stream control, as described by Mr. Stevenson (p. 142).

In Germany, the entire Emscher River is passed through settling tanks at Essen-Karnap; the Ruhr is cleaned and recleaned before it reaches the Rhine. In England the new water pollution research board, under Dr. Calvert, is attacking problems which confront all of the British river boards (p. 188).

These activities indicate that we are entering a new era in the control and alleviation of stream pollution. The interchange of knowledge between America and Europe is expedited by increasing personal contact as well as more voluminous literature.

Proceedings of Local Associations

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California Sewage Works Association

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California Sewage Works Association Second Annual Meeting

Oakland, California

October 7–19, 1929

The proceedings of the Second Annual Meeting of the California Association were printed in the October issue of THIS JOURNAL (p. 642).

The new officers elected were: *President*, F. A. Batty, Los Angeles; *First Vice-President*, B. J. Pardee, Visalia; *Second Vice-President*, W. A. Allen, Pasadena; *Secretary-Treasurer*, E. A. Reinke, Berkeley; *Director*, Alexander Bell, San Francisco; *Representative, Board of Control*, Leon B. Reynolds, Palo Alto.

Of the papers presented at this meeting the following four are published in this issue:

1. **"Cost Keeping,"** by A. K. Warren.
2. **"Fly Control at Sewage Treatment Plants,"** by W. B. Herms.

3. **"Experimental Work on Outlet Structures,"** by A. M. Rawn.
4. **"Bay Disposal and Chlorination at Newport Beach,"** by R. L. Patterson.

Abstracts of the other papers follow in the abstract section (p. 176).

New York State Sewage Works Association First Fall Meeting

Schenectady, New York

October 19, 1929

The First Fall Meeting of the New York State Sewage Works Association was held October 19, 1929, in the Hotel Van Curler at Schenectady.

A short description of the Schenectady sewage works and the waste disposal plant of the General Electric Company was given by Mr. Morris M. Cohn prior to visiting these plants.

At noon there was a meeting of the Executive Committee which was followed by a luncheon at which Mayor Henry C. Fagal delivered the address of welcome.

At 2.00 p.m. a business meeting was held. Following this the technical session began, with presentation of the following papers:

"Present Status of Sewage Treatment in New York State," by C. A. Holmquist. "The Treatment of Milky Wastes and Whey," by Prof. C. L. Walker. "The Relation of Designing Engineer to Plant Operator," by H. B. Cleveland. "The Problem of Interception and Treatment of Buffalo's Sewage," by C. L. Howell. All of these papers are published in this issue.

After dinner there was a round-table discussion on sewage works problems. The topic, "What Are You Doing to Awaken Local Interest in Your Plant?" was presented by Morris M. Cohn, who read a paper by Carl H. Watson of Great Neck, L. I., outlining his efforts in camouflaging sewage treatment plants by providing attractive superstructures and parking the grounds. Mr. Allen called attention to the marked difference between present plants and those of twenty years ago, and stated that in his opinion the newer American and German plants are in general more attractive than English sewage treatment works.

Prof. Taylor raised the question "Why Should We Attempt to Interest the Public?" A member from Syracuse stated that they invited inspection by citizens and various clubs. Mr. Biele said that in Huntington, L. I., a visit to the garbage incinerator and sewage treatment plant was required of eighth grade pupils. Mr. John F. Skinner of Rochester stated

that, although he had taken hundreds of citizens through the sewage treatment plants, he did not encourage the idea as a plant which appeared in good condition to an engineer might be very offensive to the layman. Mr. Cohn disagreed with him because the people who stayed away might think it worse than those who had seen it. Mr. Donaldson believed in encouraging the public.

Mr. John F. Skinner opened the discussion on "What Are Your Odor Problems?" He stressed the point that to have a plant free from odors it must be kept clean. Mr. Cohn found pre-chlorination effective in reducing odors but not effective in psychoda control.

The topic, "What Should this Association Do to Sponsor Sanitary Engineering Courses in Colleges of the State?" was discussed by Prof. W. C. Taylor of Union College, C. A. Holmquist, Kenneth Allen, Prof. Walker, Prof. Phelps and Mr. Cohn. It was the consensus of opinion that a four-year course is insufficient for the training of a sanitary engineer but that the course should include four years of civil engineering with a fifth year devoted to sanitary engineering or graduate study in allied lines. Special training in chemistry was stressed.

"What Do You Think of Licensing Operators?" was introduced by Mr. Devendorf, who stated that a bill was sponsored in 1922 by the State Department of Health for licensing operators, but that it failed to pass. Mr. Holmquist felt that a licensed operator might look after a number of small plants and suggested taking up the matter with the Executive Committee. Prof. Phelps was also in favor of the idea.

Mr. Cohn introduced the subject, "Is Imhoff Sludge Salable?" The Schenectady sludge was first sold at 10¢ per load, now they can get as much as 50¢ per load. If it does not compensate for the cost of selling the sludge at least it gets rid of it. The revenue amounts to about $250 per year. In Rochester, Mr. Ryan gets 50¢ for a small truck-load, $1.00 for a large truck-load or $3.00 per ton of Imhoff sludge. The revenue amounts to from $500 to $800 per year. Comparative tests on small plots with other fertilizers indicated that, for growing grass, Imhoff sludge was near the top of the list. At Marion, Ohio, Mr. Barns said that sludge was being dried bone-dry under glass, and was placed in 100-lb. bags and sold for $1.20 per bag. Mr. Skinner inquired as to whether anyone had any experience with spraying freshly-drawn sludge as a fertilizer, and Mr. Cleveland stated that this had been done at Baltimore. Mr. Allen added that before the sewage treatment plant was installed in Baltimore, night soil was disposed of by transporting it in scows to farms and spraying on areas to be fertilized. Mr. Cohn had been advised that wet sludge was being pumped on the lawns of the sewage treatment works, in the spring, at Trenton, New Jersey.

The topic "Have You a Rat Menace at Your Plant?" was discussed

by Morris Cohn who stated that the rats had undermined the foundations at the plant, in some instances, knawed holes in the wooden covers of the gas vents, and strewed screenings around the plant. Three methods had been tried to eliminate the rats, namely, trapping, poisoning and asphyxiation—the latter gave the best results. Carbon disulphide and chlorine had not been particularly effective. Calcium cyanide gave the best results. This was introduced into the holes by means of a dust pump. The dust, coming in contact with moisture, gives off hydrocyanic gas, which asphyxiates the rats. They come to the surface but do not go far.

Mr. W. A. Ryan opened the discussion on the subject of "Have You Found a Paint to Withstand Plant Conditions?" At Rochester they found that lead paint was unsatisfactory and that "nitrose" was the best black paint as it gave a glossy finish and prevented corrosion. Aluminum paint was good for iron rails, especially if the aluminum was put on top of a coat of "nitrose." "Barrelled Sunlight" or a paint with a similar base was found excellent for inside work. On concrete an emulsified road asphalt mixed 1:1 with water, was found to be a good paint. Mr. Allen remarked that Los Angeles was using a bitumastic paint on concrete and iron. Graphite paint was suggested by Mr. Cohn but Mr. Ryan said that this flaked off. Mr. Enslow stated that titanium oxide made a good white paint around sewage plants. Mr. Ryan found Toch paints to be excellent. Mr. Skinner obtained excellent results by painting underground steel pipe with a coat of graphite, red lead and raw oil, and then with a second coat containing a larger proportion of the red lead. He found "Protexol," formerly known as carbolinium abanorius, also good, especially as a wood preservative. This should be applied hot. This paint gave a black walnut stain finish and stood up under intermittent spray conditions. For sludge bed enclosures it was recommended by several members to use either galvanized material or aluminum paint. A representative of the Inertol Company discussed the uses of this product for preserving steel and concrete.

The last round-table topic was "What Phases of Plant Operation Need Research?" This was introduced by Prof. Phelps, who stressed the importance of fundamental research. As an instance, he had noticed five distinct color zones around the nozzles of the sprinkling filters of one bed, while on another with a different distributor, three color zones. These were due to biological differences and would be a good subject for fundamental research. Mr. Enslow recommended that work be done on the control of psychoda.

After the round-table discussions the meeting adjourned until dinner.

Several committees were appointed at this meeting. These were as follows:

PUBLICATION: M. M. Cohn, *Chairman;* Chas. R. Cox and Prof. C. L. Walker.

SHORT SCHOOL: Prof. E. B. Phelps, *Chairman;* M. M. Cohn, W. A. Ryan, Prof. W. C. Taylor and Prof. C. L. Walker.

LEGISLATION: C. A. Holmquist, *Chairman;* H. B. Cleveland, Wm. T. Field, John F. Skinner, Russel Suter and W. W. Young.

MEMBERSHIP: Earle Devendorf, *Chairman;* H. B. Cleveland, J. H. Feigel, F. J. Laverty, J. F. Sanborn and W. W. Young.

PROGRAM (for New York meeting): R. H. Gould, *Chairman;* E. B. Besselievre, C. L. Bogert, H. B. Cleveland and Geo. T. Hammond.

The January meeting of the New York Association will be held Jan. 18, 1930, at the Hotel McAlpin in New York City.

New England Sewage Works Association
First Fall Meeting

Worcester, Mass.

October 21, 1929

The First Fall Meeting of the New England Sewage Works Association was held at the Hotel Bancroft, Worcester, Massachusetts, October 21, 1929. There were sixty-nine members and guests present.

The meeting was called to order at 10:00 a.m. by the President, Mr. Stuart E. Coburn. In his opening remarks, Mr. Coburn stressed the value of the Association to those interested or engaged in sewage treatment, especially emphasizing the importance of *The Sewage Works Journal* which is received quarterly by members of the Association.

Three papers were presented on the "Powers and Duties of State Authorities in Relation to Establishment and Operation of Sewage Treatment Plants." The first was presented on behalf of Mr. X. H. Goodnough, Chief Engineer, by Mr. Edward Wright, Assistant Engineer of the Massachusetts State Department of Health. The second paper on this subject was given by Mr. Warren J. Scott, Director of the Division of Sanitary Engineering, Connecticut State Department of Health. Following this paper, the President called upon Mr. W. R. Copeland, Connecticut State Water Commission, to elaborate upon the policies of his department in relation to sewage treatment in Connecticut. The last paper of this group was by Mr. Eskil C. Johnson, Chemical Engineer, Board of Purification of Waters for the State of Rhode Island. All of the above papers are published in this issue.

Mr. E. Sherman Chase, of the firm of Metcalf and Eddy, Engineers,

Boston, Mass., presented a paper on the "Why and How of Sewage Treatment."

Mr. J. W. Bugbee, City Chemist, Providence, R. I., opened the round table discussion on the "Value of Plant Records and Simple Chemical and Biological Tests."

Upon motion by Mr. Scott, it was voted that the President appoint a committee to consider the problem of "Sewage Plant Records" and to report at the next meeting of the Association.

A description of the Worcester Sewage Treatment Plant, illustrated by lantern slides, was given by Mr. J. C. Brooks, Superintendent of the Worcester Sewer Department.

The session adjourned at 1:10 for luncheon.

After the luncheon Mr. Roy S. Lanphear, Supervising Chemist, Worcester Sewer Department summarized the 1929 operating results of the Worcester Sewage Treatment Plant. An inspection trip was made to this plant in the afternoon.

Notice of Spring Meeting

The Spring Meeting of the New England Sewage Works Association will be held in conjunction with the meeting of the New England Health Institute, April 15 and 16, 1930, at the Hotel Statler in Boston.

Missouri Water and Sewage Conference
Fifth Annual Meeting

Chillicothe, Mo.

October 21–23, 1929

The Fifth Missouri Water and Sewerage Conference was held in Chillicothe, October 21–23, 1929, at the City Hall. There were 83 registrations.

The first day's discussions were concerned with water treatment problems.

The papers on sewage treatment presented on the second day were as follows:

"Progress Made in Sewage Plants," by R. E. McDonnell, Consulting Engineer, Kansas City.

"Status of Sewage Treatment in Missouri," by W. Scott Johnson, Chief Public Health Engineer, State Board of Health of Jefferson City, Missouri. (Published in the October, 1929, issue of THIS JOURNAL.)

"Production and Collection of Sewage Gas," by George S. Russell, Consulting Engineer, St. Louis. Discussion by R. E. McDonnell.

"Sewage Rental Charges," by N. T. Veatch, Jr., Consulting Engineer, Kansas City. Discussion by W. Scott Johnson.

"Sewage Treatment Plant Operating Tests and Records," by H. M. Bosch, Assistant Public Health Engineer, State Board of Health of Missouri. Jefferson City. Discussion by George S. Russell.

The following officers were elected for the coming year: *Chairman:* S. J. Duncan, Moberly. *Vice-Chairman:* J. H. Wells, Joplin. *Secretary-Treasurer:* H. D. Peters, Jefferson City. *Executive Committee:* W. V. Weir, University City; E. E. Wolfe, Hannibal; W. E. Barnes, Liberty; A. E. Haecker, Poplar Bluff.

Iowa Sewage Treatment Conference Eleventh Annual Meeting

Ames, Iowa

October 22–24, 1929

The Eleventh Annual Meeting of the Iowa Sewage Treatment Conference was held October 22, 23 and 24, 1929, in conjunction with the Third Annual Meeting of the Iowa Wastes Disposal Association at the Iowa State College, Ames.

Fifty-three engineers, municipal officials and sewage treatment plant operators attended the sessions.

Lectures, laboratory instruction and round table discussions constituted the program of the Conference.

The meeting opened with an address of welcome by Prof. T. R. Agg, Assistant to the Dean of Engineering, Iowa State College.

The papers presented were as follows:

"Is Sewage Treatment Necessary?" by L. J. Murphy, Municipal Engineer, Engineering Extension Service, Iowa State College.

"Municipal Sanitation from the Viewpoint of a Mayor," by Mayor L. E. Eslick, Rockwell City.

"State Regulations Covering the Installation and Operation of Works for Sewage Treatment," by A. H. Wieters, Chief Engineer, State Department of Health, Des Moines.

"Sanitary Improvement Acts Affecting Municipalities," by Prof. Earle L. Waterman, Iowa City.

"Legal Phases of Sewage Disposal," by Frank G. Pierce, Secretary, Iowa League of Municipalities, Marshalltown.

"Screening and Skimming Sewage," by Fred G. Nelson, Sanitary Engineer, The Dorr Company, Chicago, Illinois.

"Sewage Tanks—How They Work and Why They Go Bad," by Prof. Earle L. Waterman, Civil Engineering Department, University of Iowa, Iowa City, and Lafayette Higgins, Consulting Sanitary Engineer, Des Moines.

"Selling the Sewage Treatment Plant to the Public," by Bert Stull, Supt. Sewage Treatment Plant, Storm Lake, and Milo E. Shade, Supt. Sewage Treatment Plant, Spirit Lake.

"Know Your Sewage," by Jack J. Hinman, Jr., Chief, Water Laboratory Division, State Hygienic Laboratories, Iowa City.

"The Maintenance of Sewers," by Nathan Barber, City Engineer, Waterloo.

"Financing Sewage Treatment," by Howard R. Green, Consulting Engineer, Cedar Rapids.

"Sewage Tests for Efficient Plant Operation," by Harry E. Goresline, Bacteriology Department, Iowa State College.

"Revamping Old Sewage Treatment Plants," by Fred G. Nelson, Sanitary Engineer, The Dorr Company.

"Eliminating Odors and Nuisances about the Treatment Plant," by Prof. W. E. Galligan, Civil Engineering Department, Iowa State College.

"How to Keep Sewage Filters in Operating Order," by C. H. Currie, President, Currie Engineering Co., Webster City. Discussion by Max Levine.

"The Relationship of Municipalities and Industries on the Treatment of Industrial Wastes," by L. F. Warrick, State Sanitary Engineer, Madison, Wisconsin.

"What about the Treatment of Industrial Wastes?" by Dr. Max Levine, Department of Bacteriology, Iowa State College.

A round-table discussion which followed these papers was well attended. The laboratory classes on plant tests were also given a prominent place in the program and were well attended.

The entertainment features of the meeting were a smoker on the first night and a banquet Wednesday evening in honor of Jack J. Hinman, Jr., President of the American Water Works Association. Mr. Hinman spoke on "A Sanitarian's Experiences in South America."

At the business meeting of the Association, the legislation committee's recommendation that a Sanitary District Law be placed before the State Legislature was approved. The advantages and disadvantages of licensing plant operators were discussed.

The Sewage Works Journal was also discussed and a number of the members commented on the need and also the difficulty of securing practical understandable material on plant operation, problems and difficulties.

Officers elected for 1930 were: *President:* Jack J. Hinman, Jr., Iowa City. *Vice-President:* A. H. Wieters, Des Moines. *Secretary-Treasurer:*

L. J. Murphy, Ames. *Directors:* Bert Stull, Storm Lake; Howard R. Green, Cedar Rapids. *Representatives Board of Control:* Max Levine, Ames; Earle L. Waterman, Iowa City.

North Carolina Sewage Works Association Seventh Annual Conference

High Point, N. C.

November 4–6, 1929

The Seventh Annual Conference of the North Carolina Sewage Works Association met in conjunction with the Ninth Annual Convention of the North Carolina Section of the American Water Works Association, November 4–6, 1929, at the Sheraton Hotel in High Point.

The meeting was opened at 10:00 a.m. The Mayor of High Point, Hon. C. A. York, welcomed the members and guests. Mr. McKean Maffitt, President, responded.

The morning papers were devoted to water problems.

In the afternoon, H. E. Miller, State Board of Health, Raleigh, gave a talk on "What the Water and Sewage Works Associations Mean to North Carolina." This was followed by a "Question Box Session" at which time topics on the problems of water supply and purification, sewerage, sewage and waste treatment, and stream sanitation were discussed.

In the evening, a report of the Toronto Convention of the A. W. W. A. was read and a business meeting was held.

On November 5th, the morning session was devoted to papers on sewage and sewage treatment and were as follows:

"Laboratory Control of Sewage Treatment Works," by G. F. Catlett, State Board of Health, Raleigh. (Published in this issue.)

"Natural Purification Capacities of Streams," by H. W. Streeter, U. S. Public Health Service, Cincinnati, Ohio. (Published in this issue.)

"The High Point Water Supply and Sewage Disposal Systems," by P. J. Dishner, Superintendent, Water and Sewer Departments, High Point.

Symposium on Sewage Plant Operating Results and Costs:

(*a*) "Separate Sludge Digestion and Trickling Filters," by E. H. Moss, Supt. of Plants, High Point.

(*b*) "Separate Sludge Digestion and Trickling Filters," by A. M. Worth, Supt. of Plants, Durham.

(*c*) "Imhoff Tanks and Trickling Filters," by C. C. Hommon, Supt. of Plants, Canton, Ohio.

(*d*) "Direct Oxidation, Sludge Filtration," by W. E. Thrasher, Supt. of Plants, Winston-Salem.

(*e*) "Activated Sludge, Filtration and Digestion of Sludge," by E. G. McConnell, Supt. of Plants, Charlotte.

In the afternoon a barbecue was held at the dam of the High Point water supply lake with the compliments of the City of High Point. Following this a tour was made of the High Point water purification and sewage treatment plants.

A very enjoyable banquet and entertainment was held in the evening.

Papers were presented Wednesday morning, dealing with pumping equipment, distribution and variation of annual rainfall, mosquito control on reservoirs, and preparation of state health reports.

The newly elected officers of the Associations are: *President:* McKean Maffitt, Wilmington; *Vice-President:* P. J. Dishner, High Point; *Secretary-Treasurer:* H. G. Baity, Chapel Hill; *Editor:* E. G. McConnell, Charlotte.

Reviews and Abstracts

H. W. STREETER

Abstracts of Papers at California Meeting, October, 1929

ABSTRACTED BY H. GLADYS SWOPE

Oil Exclusion and Removal from Sewers in the City of Los Angeles. BY F. A. BATTY, Engineer of Sewer Maintenance, City of Los Angeles. Grease and petroleum wastes are not only detrimental to the proper functioning of a sewage treatment plant but they are dangerous in sewers due to possible ignition. It is estimated that 22 tons of grease per day is contributed to the sewage system by one million people in Los Angeles. A short time ago a severe explosion occurred in the Slauson Avenue Outfall sewer, blowing the covers of 30 manholes into the air, due to a mixture of explosive gases in the sewer. A series of experiments has been started on grease removal and it is the intention to construct final grease removal units at the screening plant.

Sewage Disposal. BY F. C. FROEHDE, City Engineer, Pomona. The effluent from the activated sludge plant is being used for irrigation purposes. An analysis of the effluent showed it to contain 1.27 grains per gallon of nitrogen and 0.55 grains per gallon of phosphoric anhydride. Since the effluent is good for irrigation and fertilizer purposes it is being sold, and the revenue obtained from the sale during the fiscal year 1928–29 was $4668.97.

The paper was discussed by C. C. Kennedy, R. F. Goudey and T. R. Haseltine.

Sewage Disposal in California. BY LEON B. REYNOLDS, Professor of Sanitary Engineering, Stanford University. Sewage disposal in California has had its development within the last twenty-five years, and within the last fifteen years plants designed to produce an oxidized effluent have been built. This state now has 300 sewer systems and about 200 sewage treatment plants. Sewage disposal in California is effected by discharge into either fresh or salt water or in a few cases onto land. Raw sewage is disposed of by 23 per cent of the systems discharging into fresh water and by 62 per cent of those discharging into salt water. Sixteen per cent of the systems using land disposal discharge raw sewage. In San Francisco Bay there are 17 communities discharging raw sewage.

Methods of sewage treatment in California vary from the removal of coarse solids to the complete removal, as far as practicable, of all solids and bacteria. Along the coast there are seven fine-screening plants in use for

protection of bathing beaches. In the state there are 87 septic tanks, 96 Imhoff tanks, 33 trickling filters, 26 natural sand filters and 7 activated sludge plants in operation. In 19 cases chlorination is being used to destroy bacteria, and in four cases for odor control.

Slides of the various treatment plants in California were shown.

State Supervision of Sewage Disposal. By C. G. GILLESPIE, Chief, Bureau of Sanitary Engineering, Berkeley. The California State Board of Health was created in the '70's, but it was 1907 before there was an act to regulate sewage disposal, and not until 1915 was the Bureau of Sanitary Engineering established. The State has the power to regulate the treatment of sewage through the Bureau; however, it does not have the power to order the construction of sewers.

Responsibility of a Municipality in Sewage and Sewage Disposal. By B. J. PARDEE, City Manager, Visalia. The city or municipality should use its power to require industries to treat obnoxious wastes, especially if these wastes are detrimental to the proper functioning of a sewage disposal plant.

Messrs. Lee, Parkes, Crist, Smith, Forsythe, Rantsma, Steward and Perry discussed this paper.

Special Industrial Sewers and Chlorination at Tulare. By R. M. BERRYHILL, City Manager, Tulare. Tulare now has a population of 7500. Septic tanks were first used for sewage treatment, but with the growth of the city and creamery industries partial treatment was found to be insufficient. In 1925, an activated sludge plant was built, but in 1928, with the ever increasing load of dairy wastes, the activated process was ineffective for such wastes. Broad irrigation was tried but was unsatisfactory. Finally chlorination was tried and it was found that this retarded the putrefaction of the whey and that the wastes could then be run onto sewage farms. The soil could be cultivated within 16 hours after irrigation, provided the chlorinated wastes were distributed evenly over the surface of the ground.

This paper was discussed by Messrs. Perry, Gillespie, Beyer and Reynolds.

Gas Burning and Chlorination at the San Bernardino Sewage Plant. By F. S. CURRIE, Consulting Engineer, San Bernardino. The location of this plant made it imperative to control odors. The design of the plant included a 6300 ft. inverted siphon, and it was decided to chlorinate the raw sewage at the upper end of this siphon. Final chlorination is effected at the entrance to the dosing chambers. The addition of chlorine at this point must be closely controlled, as too much will destroy the purifying organisms on the filter beds. At first, chlorination at this point was regulated so as to produce a residual of 0.2 or 0.3 p. p. m. at the creek 1500 ft. below. This was considered detrimental to fish life and later the amount of chlorine was reduced to a residual of 0.1 p. p. m. in the creek.

Another factor in odor control is the collection and disposal of all gases occurring in the digestion compartments of the Imhoff tanks. The gas vents are covered. The gases are collected and stored in two 750 cu. ft. lift-type gas holders under a pressure of about 6 in. of water. As much of this gas as possible is used in a 40 h. p. gas engine connected directly to an electric generator. Any excess gas is burned.

From February to June, 1929, the gas averaged 1500 cu. ft. per day, and during the first week of June the figure rose to 5000 cu. ft. per day. During the second week this increased to 10,000 cu. ft. per day.

The paper was discussed by Mr. Kivari of the Dorr Company.

B. Coli Surveys at Los Angeles. By W. T. KNOWLTON, Sanitary Engineer, Los Angeles. B. coli surveys were made in the beach waters adjacent to the Hyperion disposal plant and along Hyperion Beach at points less than one half-mile apart and covering a distance of about two miles on each side of the outfall. Ocean surveys all along the city and near the sewer discharges were also made. Hydrogen sulphide tests were made and chlorine was applied at the plant to reduce the odors and field of pollution in the ocean. Except on Sundays and holidays, during the bathing season, the B. coli counts did not exceed ten per cubic centimeter.

Relative Costs of Sewerage. By D. E. PERRY, Manager and Assessor, Marin County Sanitary District, San Anselmo. A very small sum is obtained from taxes for the building and upkeep of sewage disposal plants in comparison with the monies obtained for schools, hospitals and charity institutions.

Imhoff Tank Operation in Stockton, California. By W. B. HOGAN, City Manager, Stockton. This plant was put in operation in 1922. It consists of a pump house, Imhoff tank of two units and levee enclosure for flood protection and water supply. The total cost of the plant was $103,000.

The sewage of Stockton contains industrial wastes from canneries, foundries and laundries. Stockton has had a great deal of trouble with foaming, which occurs on the average of 104 days per year. Hosing down with water is partially effective. The average operating costs over a seven-year period are given.

Messrs. De Martini and Kennedy discussed this paper.

Foaming and High-Rate Land Disposal at Visalia. By L. H. GADSBY, City Engineer, Visalia. Foaming is seldom experienced at this plant. This may be due to the fact that the gas vents in the Imhoff tanks are 4 ft. in width, whereas the standard width is 2 feet. A great deal of scum has been found in the vents, and this has been ascribed to the somewhat acid condition of the tank contents. Experiments indicated that a neutral or very slightly alkaline condition reduced the scum formation. Land dis-

posal of sewage has been practised at Visalia. The type of crops raised on land treated in this manner must be taken into account.

Experience with High-Rate Land Disposal. BY F. J. ROSSI, City Engineer, Modesto. A septic tank had been in use for some time, but the effluent was not considered satisfactory for discharge into the river. The topography of the land suggested high-rate land disposal. Two experimental units were constructed, the first rectangular in shape, filled with sandy loam, and the second a strip check. The effluent from the septic tank was admitted to these units. The strip-check method was ineffective. It was finally decided to install a clarifier and to use the septic tank as a temporary sludge digestor. The effluent from the clarifier will be drained into an underdrained sand bed enclosed by a 3 ft. levee.

The paper was discussed by Messrs. Gillespie, Reinke, and Mason. Mr. Gillespie said that the rates of disposal on land at Pasadena per acre per day were 10,000 gallons, at Visalia 15,000 and San Luis Obispo 20,000. In each case crops are raised. At Fresno there was a disposal rate of 60,000 gal. on land with no cropping, at Modesto 360,000 to 750,000 and at Kingsbury the sprinkling filter effluent was run on to sand at the rate of 750,000 gallons. At Carmel, the sand beds operate at a rate of 1,500,000 gallons. The figures show that the rates for merely taking up sewage are greater than those quoted on the basis of oxidized result in the percolated water.

Slough Disposal at San Anselmo. BY C. C. KENNEDY, Consulting Engineer, San Francisco. Prior to 1920, the untreated sewage from the district discharged directly into a narrow tidal slough extending three miles inland from the open water of San Francisco Bay, into which also discharged San Anselmo Creek. This slough became so grossly polluted that treatment of the sewage was necessary. Treatment works were built, consisting of two Imhoff tanks, sludge beds and chlorination equipment. Chlorination was found economically impracticable because of the high content of hydrogen sulphide. The analyses showed 70 per cent reduction of total solids and a B. O. D. reduction of 25 per cent.

Bay Disposal. BY F. M. LOCKWOOD, City Manager, San Diego. It has been the practice at San Diego to discharge the raw sewage into the bay. The objectionable conditions along the water front made some treatment necessary, and since the floating solids were most objectionable, sedimentation was considered sufficient preliminary treatment.

A tank is now being constructed on the bay side of Pt. Loma. This is a hopper-bottom tank, built to allow for 1.5 ft. depth of scum, one-hour detention period and a sludge capacity of about 1.5 cu. ft. per capita. Sludge is to be discharged upon outgoing tides. A plant is also to be constructed in San Diego, where the sewage will flow by gravity to a clarification tank, where it is estimated that 95 per cent of the settleable solids will be removed with a one-hour detention period. The objectionable solids and a great

deal of putrescible material are thereby removed, the ocean affording sufficient dilution of the effluent. The sludge from the clarifier is digested in separate digestion tanks, and the gas is collected and used in the city incinerator.

Float Surveys and Wrought Iron Pipe Outfalls at Santa Cruz. By CHAS. GILMAN HYDE, Professor of Sanitary Engineering, University of California, Berkeley. Float surveys were made in 1925 to determine current directions and velocities in order to recommend a location for outfall of fine-screened sewage in Santa Cruz Harbor. Three types of floats were used: (1) shallow surface floats made from bottles (submerged depth 9 inches) and vane floats (submerged depth 12 inches); (2) deep surface floats with light vanes (submerged depth 4 ft.) with heavy vanes (submerged depth $5\frac{1}{2}$ ft.); (3) sub-surface floats, indicating the direction of deeper currents, irrespective of surface conditions (submerged depth 20 ft.). From four locations 178 releases were made, 122 of which were shallow surface floats, 34 deep surface floats and 22 sub-surface floats. Two stations gave excellent results and the one recommended was 4800 ft. from high tide line off-shore from the mouth of San Lorenzo River, where the depth at mean lower low water was 40 feet.

Public opinion, however, would not allow this point to be accepted and so divers were employed to see if a smooth lane of rock could be found upon the surface west of the lighthouse, so that outfall pipes could be laid. Such a lane was found, but to reach the lane a force main in tunnel 4400 ft. long was required. Pipe had to be used which would withstand corrosion and the erosive action of the sand. The pipe chosen was hand-puddled wrought iron, protected by galvanized wrought ingot iron sheathing. The annular space between the sheathing and pipe was filled with cement-grout in which was imbedded a continuous band of No. 9 gauge $1\frac{1}{2}$ in. mesh galvanized wire link protection fencing. The pipe is also protected by a paint and gunite coating. The costs of pipe and installation are given.

Concrete Pipe and Pumping at San Rafael. By H. K. BRAINARD, City Engineer, San Rafael. Sewer installations from 1874 to date are reviewed. The sewage now flows by gravity to a pumping station and then is pumped to San Francisco Bay. Concrete pipe is used, laid on redwood cradles.

Discussion of Sewer Grades. By A. M. RAWN, Assistant Chief Engineer, Los Angeles County Sanitation Districts, Los Angeles. In and around Los Angeles flat grades are those which produce a velocity less than two feet per second with the pipe flowing full or half full. Other engineers designate a flat grade as that producing a velocity less than one foot per second. Sharp grades are advised so that solid waste material will not settle and clog the system, but in many cases the engineer should use discretion and depart from prescribed practice and use flat grades.

The paper was discussed by Messrs. Crist, Rantsma, Batty, Kennedy, Parkes, Perry and Wright.

Abstract of Papers Presented at the Second Annual Ohio Conference on Sewage Treatment

Marion, Oct. 31, 1928

Bulletin Issued by Ohio State Department of Health

Abstracted by K. Meagher

Four papers were presented at the Second Annual Meeting of the Ohio Sewage Conference, Oct. 31, 1928, at Marion.

Floyd G. Browne, Superintendent of the Marion Sewage Treatment Works, gave operating data from July 1, 1924 to June 30, 1928. The sewage treated is strictly domestic. A sewered population of 23,000 is tributary to the plant. The flow varied from 470,000 to 5,486,000 g. p. d., with an average of 1,450,000 equivalent to 63 gallons per capita per day. Odor nuisance from screenings was obviated by burial soon after collection. Scum racks were used with success in the gas vents of the Imhoff tanks. It was found that by keeping the Imhoff tanks as full as was consistent with good operation the probability of foaming was lessened. Nitrates in the trickling filter effluent reached a maximum of 25 parts per million. Flooding of the filters checked fly growth. In order to sink the light humus sludge on the surface of the final settling tanks, a spray of water from three whirling lawn nozzles was employed. A satisfactory final effluent averaging 20 p. p. m. suspended solids and 21 p. p. m. 5-day B. O. D. was obtained. Sludge was sold as fertilizer at a small profit either direct from the bed, weathered or pulverized.

The average annual cost of operation has been approximately $19,000.

Operating results of the plant of Sewer District 2, Hamilton County, were presented by I. N. Clover, Assistant County Sanitary Engineer. The sewers tributary to the plant serve a population of approximately 6000 north of Cincinnati. The plant includes a screen chamber, Imhoff tanks, a dosing chamber, sand filters and sludge beds. The settling tanks and sludge beds were designed for a sewage flow of 600,000 g. p. d., and the sand filters, 3 acres in area, for 300,000 gallons per day. The sewage treated from October, 1927, through September, 1928, averaged from 165,000 to 483,000 g. p. d., based on monthly averages. Two analytical surveys have been made by the State Department of Health. The first, on a catch sample collected April 3, 1928, indicated that sedimentation reduced the suspended solids from 1120 to 16 p. p. m. and the B. O. D. from 427 to 41 p. p. m.; the final filter effluent contained 4 p. p. m. suspended

solids and 10 p. p. m. oxygen demand. The flow was 387,000 gallons per day. A second analysis made on a composite sample Oct. 9, 1928, indicated a reduction, by sedimentation, of suspended solids from 352 to 112 p. p. m. and of B. O. D. from 200 to 132 p. p. m.; the final effluent contained 4 p. p. m. suspended solids, 40 p. p. m. nitrates and had a B. O. D. of 4 parts per million. The condition of the stream below the plant was excellent.

R. C. Sweeney, Assistant Engineer, State Department of Health, discussed the legal and administrative phases of the operation of small treatment works in Ohio. State power to secure proper sewage plant operation is extensive. Representatives of the State Department of Health make routine plant investigations and require monthly reports of operating results. Part-time technical supervisors, supplementing the service of the Department, make from one plant visit a month to three a week at a cost of from $10 to $100 a month. The cost of operation and maintenance is financed by sewer rental ordinances. A table is given showing seventeen Ohio towns and their populations, minimum annual charge, time of payment and general type of ordinance. The ordinance most common is that based upon volume of water consumed. The annual minimum charge is $4 per sewer connection.

Charles C. Hommon, General Superintendent of the Canton Sewage Treatment Works, presented a method for disposing of wet sludge as fertilizer. Sludge from this plant, which has a designed capacity for 135,000 people, is discharged into a suction well from which it is pumped to the highest point of the land it is to cover and distributed through open ditches. Sludge with 95 per cent water has been pumped two miles from the point of discharge and by means of an inverted siphon has been carried across a valley nearly one-half mile. The high water content reduces friction in the pipe line and facilitates distribution over the ground. It is also high in ammonia, which is readily available to the soil. An experiment on a sludge-fertilized field showed a wheat yield of 60 bu. per acre as compared to 15 bu. per acre on the control field. At present the City of Canton is not receiving revenue from the sludge, first because the value of the sludge must be determined before a price may be set, and second because the manner in which the sludge is handled does not permit sale on a common basis by the ton or yard. The cost of labor for pumping the sludge is $3.37 an hour which includes the labor of five men and the current for the motor. For a total yearly time of 864 hours the cost amounts to less than $3000.

The Application of Bleaching Powder as an Auxiliary Treatment of Sewage

BY HERBERT D. BELL

Paper No. 11, Conference of Assn. of Mgrs. of Sewage Disposal Works, Nov. 21, 1929 (England). *Surveyor*, Vol. **76**, No. 1974, Nov. 22, 1929, pp. 503–4.

ABSTRACTED BY J. K. HOSKINS

The introduction of the paper traces the history of the use of chloride of lime in sewage treatment. The text discusses in detail the personal experiences of the author with the use of this chemical under the heads of (*a*) deodorization of sewage, (*b*) auxiliary treatment of sewage (extracted in the *Surveyor*, see above), (*c*) as a precipitant and the subsequent effect of dewatering the sludge on drainage beds and (*d*) the reduction of the fly population on percolating filters.

(*a*) **Deodorization of Sewage.**—The experimental and routine use of bleaching powder at the Stratford-upon-Avon Sewage Disposal Works over a period of 18 years is described in considerable detail. This sewage is of strong domestic origin with about 30 per cent of brewing waste and is pumped through a force main 6600 feet in length to the treatment plant. Septic conditions in warm weather resulted in objectionable odors at the works, which the addition of lime to the sewage and septic tank effluent failed to remove completely. Following numerous tests the septic tank was used as a sedimentation tank only, lime added at the pumping station and bleaching powder to the sewage and tank effluent at the disposal works at the rate of 5.64 p. p. m. available chlorine, only when H_2S could be emitted by agitation of the limed sewage or tank effluent. Lime treatment amounted to 11.8 grains per gallon of calcium oxide. Aerial nuisance has thus been prevented since 1911. Detailed operating statistics of this process for a period of 5 years are tabulated. Since 1914, bleaching powder has been added to the tank influent only (prechlorination). The desirability of avoiding septic action for favorable results is stressed.

Bath adopted the chlorine deodorization method in 1926 by injecting chlorine gas into the fresh sewage at the inlet of a 5-mile force main leading to the treatment works. The amount of available chlorine used seldom exceeds 8 p. p. m. and results in complete deodorization at the works.

(*b*) **Bleaching Powder as an Auxiliary Treatment of Sewage.**—Experience at Barnsley is described, where the Haworth method of bio-aeration is practised, preceded by primary sedimentation in Dortmund tanks. In order to prevent septic conditions in the aeration units at times of overload, aluminoferric has been used as a precipitant. Under exceptional conditions last year 6 grains per gallon of this chemical was

not sufficient to maintain active purification conditions in the aeration tank and bleaching powder was substituted. The various manipulations of the plant by this method of treatment are detailed and the results presented in the form of tables. The conclusion was reached that bleaching powder will restrict septic action and thus render the work of purification more adequate in dealing with a sewage of greater strength than a plant was designed to treat, and that it is capable of revivifying humus returned to a bio-aeration unit thus enabling it to be an active purifying agency in the aeration tank.

(*c*) **Bleaching Powders as a Precipitant.**—Comparative results of precipitation during the above described treatment with aluminoferric and with bleaching powder indicate that the latter chemical acts as a precipitant in addition to restricting septic action, and in addition very beneficial effects were apparent in the drying of both the detritus and the primary settling tank sludge. Odors were eliminated by the chlorine treatment and sludge dried more rapidly increasing the capacity of the sludge beds from 19.52 to 20.88 persons per square yard.

(*d*) **The Reduction of Fly Population on Percolating Filters.**—The experiments of Cohn at Schenectady are reviewed and studies by the author at Barnsley are discussed. When bleaching powder was added once each week to the trickling filter influent in the proportion of $39\frac{1}{2}$ grams of available chlorine per square yard of filter area, assuming that the sewage liquor had no chlorine demand, and when the period of contact averaged 20 minutes, the number of flies was appreciably reduced. Moreover no harmful effects were noticeable on the *Aschorutes Viaticus* or water springtail, an effective organism for keeping the filter medium clear of slimy growth; in fact the numbers appeared to increase, indicating that the filamentous growths which form the matrix of the slimy growth have not been rendered unsuitable as food, although the slimy growth itself is rendered unsuitable to act as host to Psychoda larvae.

The Permissible Loading of a Stream with Sewage

BY DR. ING. MAHR, RUHRVERBAND, ESSEN

Technisches Gemeindeblatt, **32** (Aug. 5-20, 1929)

ABSTRACTED BY G. P. EDWARDS

Storm water as well as dry-weather flow should be included as sewage. The proportion of storm water to dry-weather flow varies greatly according to local conditions. In Germany it amounts to one-third or one-fourth of the total flow. Records at the Essen-Frohnhausen plant for the year 1915 indicate that 400,000 cu. m. of sewage and 310,000 cu. m. of storm water were received.

Pollution of streams may be due to three factors which are of approximately equal importance: (*a*) suspended solids of the dry-weather flow, (*b*) dissolved and colloidal matter of the dry-weather flow and (*c*) storm water.

Self-purification depends on microörganisms, which feed on the organic matter of the sewage. If odors of putrefaction and other nuisances are to be prevented, the decomposition must proceed in the presence of oxygen. The dissolved oxygen in the water is utilized in proportion to the biochemical oxygen demand.

One of the most complete investigations of a polluted river was made on the Illinois River, which receives all the raw sewage of Chicago, diluted with about six volumes of clean water from Lake Michigan. According to the Report of the Engineering Board of Review of the Sanitary District of Chicago, remarkable variations in the oxygen content at the different stations from month to month are due mainly to changes in temperature. The dissolved oxygen is, of course, higher in winter than in summer. In the winter, the river is stable after 4 to 5 days and in summer after 8 to 10 days. During the cold weather the oxygen content of the river is high, the biological action slow, and much sludge is deposited on the river bottom. In the summer months when the solubility of oxygen in water is lower and biological action is faster, the oxygen requirements are greater as, in addition to the sewage, the large oxygen demand of the deposited sludge must be cared for. Since re-aeration depends only on the percentage of saturation and not on the absolute oxygen content (mg. per liter) re-aeration is faster in winter than in summer.

Three important factors in the self-purification of polluted streams are (1) time necessary for decomposition, (2) the amount of dilution of the sewage in the river and (3) the surface, which admits light and air. The time necessary for sewage to decompose varies according to the type of disposal. For example, the Illinois River requires 8 to 10 days, fish ponds about 3 days and activated sludge 3 to 10 hours, according to the process.

Kolkwitz has shown that fine river sludge under favorable conditions has properties similar to activated sludge. The colloids are removed by adsorption, the organisms which live on the sludge floc utilize the organic matter and thus renew the adsorbing power of the floc.

One-and-a-half year's operation on the Ruhr River has shown the effect of time on purification. The purifying power was considerably increased when the two or three-day period of flow from Hagen to the mouth of the river was doubled.

The dilution requirements vary greatly. Dilution ratios formerly considered satisfactory have been shown to be unsatisfactory in view of the many other factors involved. The actual dilution ratio must be based upon a balance of the oxygen resources and the oxygen demand.

The speed of oxygen absorption depends upon the degree of saturation. Values for re-aeration in various rivers are as follows: in the Spree, which receives some of the sewage from Berlin, about 2 gm. per sq. meter per day; in the Havel, an average of 2.5 gm. per sq. m. per day; in the lower Rhine, from Coblenz to the Dutch border, which is less polluted than the Berlin stream, only 1 gm. per sq. m. per day; in the Illinois River from Lockport to Chillicothe 11 gm. per sq. m. per day; and in the stretch Lockport to Henry, where the decomposition of soluble substances takes place, 7 gm. per sq. m. per day. Some values for short stretches of river are as high as 30 gm. per sq. m. per day, according to some American figures.

In a rather highly polluted stream the time of decomposition of the sewage can be divided into two periods. The first and most important period, during which the oxygen decreases, is short, lasting only two or three days. The rate of oxygen absorption is higher than in the second period. About half the total demand is satisfied. For satisfactory conditions, the surface of a stream must be large enough to absorb sufficient oxygen to satisfy half the total demand in the first two days. The second period, in which the oxygen content increases to the saturation point, is longer. The place where the dissolved oxygen is lowest is the critical point.

In general, when the sewage is treated in mechanical clarification plants, a stream surface of about 10 sq. meters per capita is necessary. For instance, the inner city of Amsterdam discharges its sewage into the Grachten whose surface is equivalent to only 5 sq. meters per capita. In summer strong disagreeable odors are present. In the Ruhr, the time of flow through the lake is the same as through the river. However, the surface of the lake is considerably smaller than that of the river and in spite of the equal length of time, the lake cannot purify as much fresh sewage as the river.

The Problem of Phenol Wastes

BY DR. MAX PRÜSS

Das Gas und Wasserfach (Aug. 10, 1929)

ABSTRACTED BY G. P. EDWARDS

Considerable damage to fish and drinking water supplies is caused by the 10,000 tons of phenol annually discharged from seventy-five coke plants in the Emscher District.

A great deal of experimental work has been done on the removal of phenol. Bach has developed an aerated slag filter which reduced the

permanganate oxygen consumed from 10,000–40,000 to 600–800 parts per million. About 8 cu. ft. of air per gallon of waste in a 2-hour detention period are necessary. Four-fifths of the effluent is returned and mixed with raw waste, diluting it 4 to 1. These filters were successful but the cost of operation was high.

Quenching of the coke with the waste is not successful as it must be done far from residential sections and sensitive vegetation, which it destroys.

Four phenol recovery plants using the Pott-Hilgenstock method have been erected. In this process, the phenol is extracted with benzol from the ammonia liquor before the ammonia is removed, thus eliminating losses of benzol. The benzol is distilled from the phenol and re-used. About 90 per cent of the phenol is recovered and sold. The cost of steam for distillation amounts to more than half the total cost of recovery. In order to reduce this cost, phenol has been removed with sodium hydroxide.

The Koppers Company process used in America removes the phenol by passing a large quantity of gas heated to 102° C. through the hot ammonia waste liquor. A solution of sodium hydroxide is used to extract the phenol from the gas. About 95 per cent of the phenol is recovered by this method.

Bach filters can be used to supplement the extraction processes.

Brown coal waste is stronger and more difficult to treat than ordinary coal wastes. In order to use biological treatment, sulphur compounds, oil and tar must be removed and a higher dilution is necessary. The phenols may be extracted with benzol or toluol followed by the removal of phenol with sodium hydroxide or distillation. Non-volatile oils insoluble in water may be used and regenerated with sodium hydroxide.

For the recovery of phenol from gas wash waters, an oil with a specific gravity of 1.04, boiling between 320° and 350° C. has been used satisfactorily.

Large deposits of sludge containing tar and phenol are found in the Emscher River. In order to prevent the sludge from being washed into the Rhine during storms, the entire flow of the Emscher is settled in a new treatment plant. It is estimated that 250,000 cu. meters of sludge per year will be collected.

Dr. Miller (Frankfurt a.M.) in a discussion which followed the reading of the paper suggested filtration of phenol wastes through carbon in order to avoid the use of large quantities of benzol. The phenol can easily be extracted from the carbon with smaller quantities of benzol. Regeneration by steam causes the carbon to lose its adsorptive power so that it must be replaced frequently.

British Water Pollution Research Board

Summary of Current Literature

January, 1930

BY H. T. CALVERT

ABSTRACTED BY H. GLADYS SWOPE

The first edition of a new British abstract journal was published January, 1930. This is a monthly review devoted to water supplies, analysis and examination of water, sewage, trade waste waters and pollution of natural waters. It is published by the Department of Scientific and Industrial Research under the direction of Dr. H. T. Calvert, Director of the Water Pollution Research Board, London, England.

The abstracts in this journal are complete summaries of articles in all of the current periodicals. In this first issue under the section "Sewage," articles are summarized dealing with sewage treatment plants in Great Britain, Germany and the United States; chemical analyses as applied to sewage problems; research problems in sewage treatment; activated sludge problems and applications on the continent and in America; and research on analytical methods. Book reviews dealing with sewage treatment are also covered in this section.

In the section on "Trade Waste Waters," papers are reviewed dealing with removal of oil, separate treatment of industrial wastes, phenol wastes, wastes from metal workings, volatile combustible liquids and wool washing wastes.

Under "Pollution of Natural Waters," regulations regarding such pollution and pollution of specific streams are discussed.

At the end of the bulletin there is a miscellaneous section in which rainfall, hydrological data, drying of solids, diffusion rate of gases and liquids and analytical determinations are reviewed.

Copies of these abstracts may be obtained through H. M. Stationery Office at Adastral House, Kingsway, London, W. C. 2. or the Department of Scientific and Industrial Research, 16 Old Queen Street, Westminster, London, S. W. 1.

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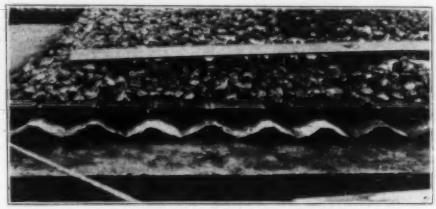

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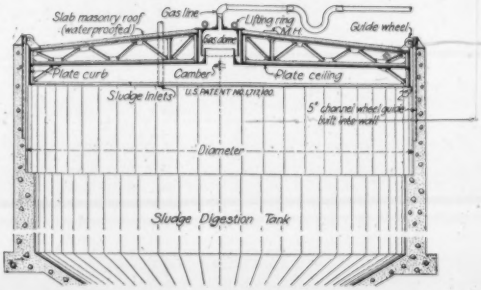

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Statement of the Ownership, Management, Circulation, etc., Required by the Act of Congress of August 24, 1912, of Sewage Works Journal, published quarterly at Easton Pa., for October 1, 1929.

State of New York }
County of Manhattan } ss.

Before me, a Notary Public in and for the State and County aforesaid, personally appeared William W. Buffum, who, having been duly sworn according to law, deposes and says that he is the Business Manager of the Sewage Works Journal and that the following is, to the best of his knowledge and belief, a true statement of the ownership, management (and if a daily paper, the circulation), etc., of the aforesaid publication for the date shown in the above caption, required by the Act of August 24, 1912, embodied in section 411, Postal Laws and Regulations, printed on the reverse of this form, to wit:

1. That the names and addresses of the publisher, editor, managing editor and business managers are:

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Publisher, Federation of Sewage Works Associations, c/o H. E. Moses, Pa. State Dept. of Health, Harrisburg, Pa.

Editor, Dr. F. W. Mohlman, 845 South Wabash Avenue, Chicago, Ill.
Managing Editor, Dr. F. W. Mohlman, 845 South Wabash Avenue, Chicago, Ill.
Business Manager, William W. Buffum, 654 Madison Avenue, New York City
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2. That the owner is: (If owned by a corporation, its name and address must be stated and also immediately thereunder the names and addresses of stockholders owning or holding one per cent or more of total amount of stock. If not owned by a corporation, the names and addresses of the individual owners must be given. If owned by a firm, company, or other unincorporated concern, its name and address, as well as those of each individual member, must be given.)

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WM. W. BUFFUM, Business Manager.

Sworn to and subscribed before me this 23rd day of September, 1929.

(Seal) THERESA A. KRAUS.
Notary Public, Bronx County, Clerk's No. 242.
Bronx County Register's No. 3140A.
(My commission expires March 30, 1931)

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